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AN ECOLOGICAL STUDY OF SEASONAL VARIATION OF ALGAL AND FUNGAL FLORA OF THE LAKES OF BHOPAL

PROJECT REPORT

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CHAPTER-I

INTRODUCTION

Extensive researches have brought to light immense knowledge about the floristic patterns and distribution of various groups of algae in many parts of our country. But still there are vast areas which are unexplored and therefore, we do not have a clear understanding of the algae of these areas. Madhya Pradesh is one such state where algal studies have not received the required attention, though algae are abundant in this part of the country. Of course, a few references dealing with the occurrence of a few members of algae in a few areas are available. But so far a systematic study has not been carried out in order to get a clear picture of the ecological aspects and the composition of the algal flora of any areas.

In an aquatic eco-system, its components are producers like Algae, consumers like zooplanktons to fishes and decomposers like fungi and bacteria. Fungi are responsible for the decomposition of organic matter and mineral recycling. The process of mineral recycling occurs either directly or by the saprophytic activities or parasitic activities of these organisms.

Fungi, the 'scavenger' of nature vary greatly in their morphology and range from unicellular holocarpic chytridiaceous forms to multicellular large filamentous eucarpic structures commonly known as 'water molds' or 'fish molds' belong to saprolegniaceae. Study of this important group of fungi remained neglected till first half of the nineteenth century. A few contributions in U.S.A. and U.K. were made in the study

In Madhya Pradesh the only known research work in the field of aquatic mycology is that of Rajgopalan and Saxena (1958) from Sagar and the other from Hasija and Batra (1971) on the ecology of Achlya americana.

Keeping in view the paucity of informations pertaining to the aquatic fungi of Madhya Pradesh, it was endeavoured to find out aquatic mycoflora , their seasonal variations along with the impact of various physico-chemical characters of water like temperature, pH, total alkalinity, dissolved oxygen, calcium hardness, chloride, nitrite, nitrate and phosphate content of water on the occurrence and distribution of aquatic fungi of the two lakes of Bhopal.

The present work is first of its kind towards this direction. The project was undertaken to study the following aspects:-

1. The algal and fungal flora of the two lakes of Bhopal, Upper Lake and Lower Lake.
2. The seasonal variations of the algal and fungal flora of both the lakes
3. The variations in the physico-chemical parameters such as temperature, dissolved oxygen, pH, alkalinity, calcium hardness, chloride, nitrite, nitrate and phosphate and their effect on the occurrence of algal and fungi of the two lakes and
4. The effect of man made disturbances on the population of algae and fungi.

CHAPTER 2

BHOPAL, ITS LAKES AND CLIMATE

Bhopal, the city of lakes and hills, is capital of Madhya pradesh, the largest state in India. It is situated on 23° 16' N latitude and 77° 25'E longitude, on hard pink-red sand stones of Vindhyan region. It is about 503 meters above mean sea level.

There are a number of water bodies in Bhopal, including lakes, ponds, pools, ditches and hilly streams. But the most famous of them are the twin lakes of the city, commonly known as 'Bara Talab' and 'Chhota Talab' also called Upper Lake and Lower Lake respectively.

Upper Lake is partly influenced by human activities and it is the main source of drinking water for Bhopal city, was constructed by Parmar King, Raja Bhoj of Dhar, after damming the seasonal river Kolans (Fig.1)

Another water body , Lower Lake is situated in the heart of Bhopal city. Its major part is surrounded by schools, colleges and residential houses, thus covered by a thick population on all sides (Fig.2).

Climate of Bhopal

The periodic adjustment of the atmospheric factors, here forms a typical monsoon type of the tropical climate. This rhythmic change in the climate brings about four distinct types of seasons:

Monsoon - June to September
Post-monsoon - October to November
Winter - December to February
Summer - March to May.

Temperature

The temperature is quite fluctuating according to seasons. The mean maximum atmospheric temperature in the year reaching in May is as high as 42°C and mean minimum temperature in the month of January i.e. 10.5°C.

Humidity:

The humidity varies from 15% to 90% during south-west monsoon. It is usually above 70% which sometimes reaches upto 90% in the month of August. The air in general is dry for the rest of the year.

Rainfall:

The average annual rainfall at Bhopal is about 920 mm. The rainest month of the year is August and April is the driest.

CHAPTER 3

MATERIAL AND METHODS

Four sampling sites in each lake were selected for the purpose of collecting water and algal samples. These sites represented the lakes for nearly all the directions. Algal samples were collected every month from each sampling site but from a depth not more than 2.5' . Regular field-notes were prepared for each collection.

Water samples were also collected from each site every month on the same day of algal collection. Water temperature was noted at the site itself by using a thermometer. The methods for analysis of water were followed as described in the "Standard Methods for Examination of Water and Waste water", 12 Ed., American Public Health Association (1965).

For the representation of data, each lake has been considered as an individual unit and the average value of physico-chemical factors of all the four sites for each lake have been taken into consideration. Monthly occurrence of algae of both the lakes was correlated with values of various physico-chemical parameters.

The water samples for the isolation of aquatic fungi were collected from the same sampling sites of Upper and Lower Lakes of Bhopal, from where algal samples were collected.

Method of Isolation, Culture and Identification of Fungi

The water samples brought to the laboratory for the isolation of fungi were processed according to the procedure followed by Johnson (1956, 1973), Sparrow (1960) and Scott (1961). The samples were shaken thoroughly and placed in sterilized Petridishes of 12.5 cm. size. To this water, was added organic baites of different types. Each Petridish was baited either with the same kind of bait or a mixture of different types of baits. The baites used for the isolation of fungi were hemp seeds (*Cannabis sativa*), wheat granins, mustard seeds, ants, snakes' skin caste and treated grass leaves (common lawn grass boiled in 90% alcohol, washed thoroughly with sterilised water and again boiled in sterilised water for two minutes). In each Petridish 4-5 hempseed halves or a few boiled mustard seeds (with seed coats removed) or 3-4 boiled wheat grains or some small pieces of sterilised snake's skin were added. These baites were examined after twenty four hours. If there was any growth then it was again washed thoroughly, in a flow of sterilised tap water and transferred to another Petridish containing sterilised water alongwith some additional fresh baites. This process was repeated till an uncontaminated healthy fungal colony appeared on the baits. Very small quantity of streptomycine sulphate was added to the water culture in order to prevent bacterial contamination. The fungi were either examined directly under the microscope or else cultured on artificial media such as plain agar; Ypss agar or corn meal-agar by transferring hyphal tips or by single spore.

The constituents of the Ypss agar and cornmeal agar media were used in the following proportions:

Linear Ypss agar media - Yeast extract - 4gm., soluble starch-15 gm. KH_2PO_4 - 1gm, $MgSO_4 \cdot 7H_2O$ -0.5 gm and Agar-Agar - 17 gm. The quantity was made up to 1000 ml.

Cornmeal agar media -corn meal -20 gm, Dextrose Lenear 0.20 gm., Agar-Agar -17 gm. and the quantity was made up to 1000 ml.

Since these cultures could not be maintained for long periods, and the growth of most of the fungi were not satisfactory on these media, thus most of the observations were based on the water cultures. After attaining a luxurient growth, these water cultures were kept at low temperature, ranging from 5 to 15°C. Mature fungal forms alongwith reproductive structures preserved in a preservative consisting of formaline, glycerine and 90% alcohol (all in equal proportions).

Some fleshy fruits like apple, were also diped directly in the water at sampling site, so as to collect members of Blastocladiaceae. During the sampling of water, some algal specimens of that region were also collected and brought to the laboratory for examination in order to identify parasitic forms.

The camera lucida diagrams were made from freshly isolated fungal forms. Identification of these forms were made by referring to books and monographs of Coker (1923), Johnson (1956), Sparrow (1960), Scott (1960) and Seymoure (1970).

CHAPTER - 4

OBSERVATIONS

A. PHYSICO-CHEMICAL CHARACTERISTICS OF WATER

Details of the physico-chemical characteristics of water of both the lakes from July, 1979 to June, 1981 are given below:

Table 1 Temperature

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			M
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	J
1979-80	24.7	22.	27.3	27.8	22.8	19.3	20.1	21.0	29.3	30.7	31.8	31
1980-81	23.8	23.1	26.5	27.1	22.0	16.3	18.3	23.3	29.0	31.1	32.6	3

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			M
Year	Ju.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb	Mar.	Apr.	May	J
1979-80	25.3	23.0	28.2	28.3	24.	20.0	20.2	22.1	29.6	30.3	31.3	3
1980-81	24.6	23.6	26.8	27.0	23.1	6.7	18.5	22.8	27.6	29.6	32.1	3

Table 2

Dissolved Oxygen in Water (mg/l)

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mo
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Ju
1979-80	7.8	8.3	10.1	10.6	10.1	10.0	8.2	8.3	7.	7.1	7.6	7
1980-81	8.1	9.5	7.9	8.4	7.8	8.4	8.6	9.9	7.9	7.2	7.1	7

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
79-80	13.2	15.5	11.6	6.8	6.2	10.0	7.9	12.4	14.4	11.6	12.5	8.0
80-81	7.1	13.1	13.9	8.4	5.3	5.5	4.2	8.2	8.4	7.2	8.2	8.6

Table 3

Hydrogen ion concentration of water

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon
ear	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun
979-80	7.9	7.8	7.7	7.9	8.2	8.6	8.2	7.9	8.3	8.7	8.6	8.5
0-81	7.9	7.8	7.4	7.9	8.2	7.9	8.2	7.8	8.3	8.4	8.5	8.5

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon
ar	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun
9-80	7.6	7.5	7.9	7.5	7.7	7.7	7.4	7.7	8.2	8.2	8.3	8.2
0-81	8.2	7.6	7.7	8.0	7.5	7.6	7.7	7.8	8.1	8.4	8.4	8.6

Table 4

Total alkalinity of water (mg/1)

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apri.	May	Jun.
80	94.2	77.5	112.0	104.7	85.0	81.5	100.0	84.5	113.5	124.0	121.5	122.0
81	122.0	108.7	122.0	100.5	103.2	114.0	94.0	76.0	107.0	115.0	124.0	116.0

Table -5

Calcium hardness (mg/l)

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
Year	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	32.7	26.5	29.7	24.5	20.0	14.5	33.5	37.5	35.5	35.0	41.5	40.0
1980-81	36.0	34.5	35.5	24.0	23.0	24.2	30.5	31.5	32.7	34.5	37.0	37.0

LOWER LAKE

	Monsoon			Post-Mon		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	57.2	56.5	60.0	66.5	69.5	66.7	80.2	83.0	66.2	67.0	73.0	84.5
1980-81	72.2	77.2	79.2	80.0	71.0	72.2	76.5	68.7	69.0	77.0	64.5	66.0

Table - 6

Chloride (mg/l)

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Ju
1979-80	13.8	10.7	9.4	11.0	11.0	12.2	10.3	11.0	12.3	12.7	12.8	1
1980-81	15.2	12.7	10.0	11.3	12.3	11.0	9.3	10.1	10.9	11.9	12.1	1

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1979-80	119.5	115.7	126.7	132.7	112.0	122.7	105.0	125.0	124.0	134.2	140.2	123.2
1980-81	142.0	121.7	134.0	126.0	122.5	113.5	128.2	137.7	134.2	127.7	122.0	113.0

LOWER LAKE

	Monsoon		Post-Mon.			Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov	Dec.	Jan.	Feb.	Mar	Apr	May	June
1979-80	32.7	28.8	28.3	28.5	2375	36.7	34.2	37.5	37.5	42.3	48.7	50.
1980-81	39.2	28.0	28.5	28.2	23.8	27.7	24.2	23.2	30.3	27.1	25.8	30.

Table - 7

Nitrate (mg/l)

UPPER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	0.10	0.12	0.09	0.10	0.05	0.07	0.09	0.17	0.06	0.06	0.03	0.0
1980-81	0.08	0.11	0.08	0.08	0.05	0.08	0.11	0.05	0.03	0.05	0.05	0.0

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	0.04	0.13	0.09	0.06	0.01	0.11	0.13	0.11	0.13	0.05	0.03	0.0
1980-81	0.08	0.15	0.19	0.16	0.10	0.09	0.06	0.04	0.03	0.04	0.03	0.0

Table - 8

Nitrite (mg/1)

UPPER LAKE

	Monsoon			Post-Monsoon		Winter			Summer			Mon.
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	nil.	0.003	0.006	0.004	-	-	-	0.003	0.003	0.004	0.008	0.005
1980-81	-	0.006	0.003	0.003	0.003	-	-	0.005	0.002	0.002	0.005	0.005

LOWER LAKE

	Monsoon			Post-Mon.		Winter			Summer			Mon
Year	Jul	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	0.005	0.007	0.006	0.008	0.003	0.003	0.004	0.015	0.011	0.007	0.003	0.003
1980-81	0.004	0.003	0.003	0.001	0.008	0.005	0.005	0.004	0.014	0.014	0.009	0.006

Table - 9

Phosphate (mg/l)

UPPER LAKE

	Monsoon			Post-Monsoon		Winter			Summer			Mon.
Year	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	0.03	0.05	0.04	0.08	0.03	0.01	0.11	0.03	0.05	0.06	-	-
1980-81	0.11	0.05	0.02	0.04	0.01	0.02	0.09	0,01	0.05	0.05	-	-

LOWER LAKE

	Monsoon			Post-Monsoon		Winter			Summer			Mon.
Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1979-80	0.03	0.05	0.05	0.11	0.08	0.14	0.08	0.05	0.05	0.06	0.03	0.03

B. BIOLOGICAL OBSERVATIONS

Upper and Lower lakes support the growth of a number of aquatic angiosperms, some of them serve as host for aquatic fungi The most common ones found in both the lakes were;

Myriophyllum spathulatum Blatt and Halb,
Ceratophyllum demersum Linn.
Hydrilla verticillata (L.f.)Royle.
Utricularia flexiuosa Vahl.
Vallisnaria spiralis Linn.
Ludwigia repens Linn.
L. perennis Linn.
L. diffusa Buch Ham.
L. parviflora Roxb.
L. prostrata Roxb.
Najas minor Allione
Potamogeton pectinatus Linn.
P. arispus Linn.
P. perfoliatus Linn.
Ipomoea aquatica Forsk
Nymphaea cynea Roxb.
N. stellata Willd.
Nelumbo mucifera Geartn.
Nymphoides cristatum (Roxb.) O. Kuntze
Pistia stratioites Linn.
Eichhornia crassipes (Mart) solms.
Polygonum barbatum Linn.
Trapa bispinosa Roxb.
Lemna pauchiocostata Linn.
Spirodela polyrhiza Linn.

Order - Tetrasporalos

Palmella mucosa Kuetzing

Sphaerocystis schroeteri Chodat

Gloeocystis gigas (Kuetz.) Lagerheim

G. ampla (Kuetz.) Lagerheim

Asterococcus limneticus Smith

Order - Ulotrichalos

Utothrix moniliformis Kuetzing

U. tenuissima Kuetzing

U. tenerrima (Kuet.) Kuetz.

Uronema africanum Borge

U. confervicolum Lagerheim

U. elongatum Hodgetts

Geminella interrupta (Turp.) Lagerheim

G. protogenita (Kuetz.) West

Cylindrocapsa geminella Wolle

Pearsoniella variabilis Fritsch and Rich

Order - Chaetophoralos

Stigeoclonium flagelliferum Kuetz.

S. nanum Kuetz.

S. Polymorphum (Franke) Heering

Aphanochaete repens A. Braun

Protococcus virdis Agardh

Coleochaete nitellarum Jost

C. orbicularis Pringsheim

C. pulvinata A. Braun

C. pulvinata A Braun vor. *indica* Prasad

C. scutata Breb.

C. soluta (Breb.) Pringsheim

Chaetosphaeridium globosum (Nordst.) Kelebahn

Order - Ulvales

Schizomeris leibleinii Kuetz.

Order - Oedogoniales

Oedogonium ambiceps (Jao) Tiffany

O. foveolatum Wittr.

O. intermedium Wittr. and Nordst.

O. iowense Tiffany

O. patulum Tiffany

O. pusillum Kirchner

O. plusiosporum Wittr.

O. pseudospirale. Nygaard

O. tapeinosporum Wittr.

O. foveolatum Wittr. var. *indicum* Goyal

Bulbochaete reticulata Nordst.

Order - Cladophorales

Cladophora glomerata (L.) Kuetz.

C. fracta (Dillw.) Kuetz.

Rhizoclonium crassipellitum West and West

R. hieroglyphicum var. hosfordii (Wolle) Collins

Order - Chlorococcales

Chlorococcum humicola (Naeg.) Raben.

C. infusionum (Schrank) Meneghini

Ropalosolen cylindricus (Lambert) Fott

Characium acuminatum Braun ex Kuetz.

C. ambiguum Hermann

C. angustum A. Braun

C. orissicum Philipose

C. pringsheimii Braun

Schroederia planctonica (Skuja) Philipose

S. spiralis (Printz) Korsh.

S. setigera (Sehroeder) Lemm.

Trochiscia granulata (Reinsch) Hansg

Gloenkinia radiata Chodat

Micractinium pusillum Frosenius

Pediastrum angulosum (Ehr.) Meneghini var. laevigatum Racib.

P. ovatum (Ehr.) A. Braun

P. duplex Meyen

P. duplex Meyen var. subgranulatum Racib.

P. duplex Meyen var. reticulatum Lagerheim

P. simplex (Meyen) Lemm.

P. simplex (Meyen) Lemm. var. duodenarium (Barley) Racib.

P. tetras (Ehrenb.) Ralfs

P. tetras (Ehrenb.) Ralfs var. tetradon (Corda) Hans.

Sorastrum americanum (Bohlin) Schmidle

S. spinulosum Naegeli

Hydrodictyon reticulatum (Linn.) Lagerheim

Tetraedron asymmetricum Prescott.

T. bifurcatum (Wille) Lagerheim

T. gracile (Reinsch) Hansg.

T. gracile (Reinsch) Hansg. fa. minus Philipose

T. incus (Teiling.) Smith

T. minimum (A. Br.) Hansg.

T. minimum (A.Br.) Hansg. var. scrobiculatum (Lagerheim)De Toni

T. minimum (A.Br.) Hansg. fa. apiculatum (Reinsch) De Toni

T. minimum (A.Br.) Hansg. fa. tetralobulatum (Reinsch) De Toni

T. muticum (A.Br.)Hansg.

T. pentaedricum West and West fa. minor west and west

T. pusillum (Wallich) West and West

T. regulare Kuetzing

T. regulare Kuetzing var. granulata Prescott

T. trigonum (Nageli) Hansg.

T. trigonum (Naegeli) Hansg. fa. gracilis Reinsch

Closteridium siamensis (West and West) Smith
Closteridium sp. nov 1.
Closteridium sp. nov. 2.
Chodatella quadriseta Lemm.
C. quadriseta fa. nov
Chlorella vulgaris Beyer
Gloetaenium loitlesbergerianum Hansg.
Oocystis borgei Snow
O. crassa Wittr.
O. elliptica West
O. gigas Archer fa. *minor* West and West
O. irregularis (Petkot) Printz.
O. solitaria Wittr.
Nephrocytium agardhianum Naegeli
N. lunatum West
N. obesum West
Botryococcus braunii Kuetzing
Dictyosphaerium ehrenbergianum Nageli
D. pulchellum Wood
Westella botryoides (West) de Wildeman
Dimorphococcus lunatus A. Braun
Ankistrodesmus convolutus Corda
A. falcatus (Corda) Ralfs
A. falcatus (Corda) Ralfs var. *acicularis* (A.Br.) West
A. falcatus (Corda) Ralfs var. *radiatus* (Chodat) Lemm.
A. spiralis (Turner) Lemm.
Actinastrum hantzschii Lagerheim
Selenastrum bibarianum Reineh
S. gracile Reinseh
S. westii Smoth
Kircheneriella contorta (Schmidle) Bohlin
K. lunaris (Kirchner) Moebius
K. obesa (West) Schmidle
Coelastrum cambricum Archer var. *intermedium* (Bohlin) West

C. microporum Naageli

C. proboscideum Bohlin

C. scabrum Reinsch

Coelastrum sp. nov.

Crucigenia crucifera (Wolle) Collins

C. quadrata Morren

C. rectangularis (A. Br.) Gay

C. tetrapedia (Kirch.) West and West

Tetrastrum staurogeniaeforme (Schroed.) Lemm.

Tetrallantos lagerheimii Teiling

Elakatothrix viridis (Snow) Printz.

Planktosphaeria gelatinosa Smith

Myrmecia aquatica (Printz) Smith

Radiococcus nymbatus (de Wildem.) Schmidle

Tetradesmus wisconsinense Smith

Scenedesmus abundans (Kirch.)Chodat

S. abundans (Kirch.) Chodat var. brevicauda Smith

S. abundans (Kirch.) Chodat var. brevicauda Smith fa. nov.

S. abundans (Kirch.) Chodat var. brevicauda Smith fa.

S. abundans (Kirch.) Chodat var. hyparabundans (Gutu.) Compere

S. abundans (Kirch.) Chodat var. skujae Compere

S. arcuatus (Lemm.) Lemm.

S. armatus (Chodat) Smith

S. armatus (Chodat) Smith

S. armatus (Chodat) Smith var. bicaudatus (Cugl.)Chodat

S. armatus (Chodat) Smith var. dispar Philipse

S. armatus (Chodat) Smith var. boglariensis Hortob

S. armatus (Chodat) Smith var. nov.

S. armatus (Chodat) Smith fa. nov.1

S. armatus (Chodat) Smith fa. nov.2

S. bijugatus (Turpin) Kuetz. var. alternas (Reinsch) Hansg.

S. bijugatus (Turpin) Kuetz. var. graevenitzii (Bernard) Philipose

S. bijugatus (Turpin) Kuetz. fa. *irregularis* Wille

S. bijugatus (Rupin) Kuetz. fa. *parvus* Smith

S. brasiliensis Bohlin

S. denticulatus Lagerheim

S. denticulatus Lagerh. var. *australis* Playfair

S. denticulatus Lagerh. var. *australis* Playfair fa. nov.

S. denticulatus Lagerh. var. *lunatus* West and West

S. dimorphus (Turpin) Kuetzing

S. dimorphus (Turpin) Kuetz. var. *longispina* Compere

S. hysterix Lagerh.

S. hystrix Lagerh. var. nov.

S. incrassatulus Bohlin

S. obliqus (Turpin) Kuetzing

S. opoliensis Richter var. *mononensis* Chodat

S. parisiensis Chodat fa. *minus* Philipose

S. platydiscus (Smith) Chodat

S. platydiscus (Smith) Chodat var. nov.

S. quadricauda (Turpin) Breb.

S. quadricauda (Turpin) Breb. *bicaudatus* Hansg.

S. quadricauda (Turpin) Breb. var. *longispina* (Chodat) Smith

S. quadricauda (Turpin) Breb. var. *eualternas* Proschk

S. quadricauda (Turpin) Breb. var. *quadrispina* (Chodat) Smith

S. quadricauda (Turpin) Breb. fa. nov.

Scenedesmus sp. nov. 1

Scenedesmus sp. nov. 2.

Order - Zygnematales

Family - zygnemataceae

Mougeotia disjuncta Transeau

M. floridana Transeau

M. miamiana Transeau

M. transeaui Collins

M. virescens (Hassal) Borge

Zygnema gangeticum Rao.

Z. mirificum Jao

Zygnemopsis sphaerospora Randhawa

Spirogyra elliptica Jao

S. hymerae Britton and Smith

S. inflata (Vaucher) Kuetzing

S. tenuissima (Hass.) Kuetzing

Family - Mesotaeniaceae

Gonatozygon aculeatum Hast.

G. brebissonii De Bary var. *laeve* (Hilse) West and West

G. monotaenium De Bary

G. monotaenium De Bary var. *pilosellum* Nordst.

Netrium digitus (Ehrenb.) Itz. and Rothe

Family - Desmidiaceae

Penium cylindrus (Ehrenb.) Breb.

Closterium acerosum (Schr.) Ehrenb.

C. aciculare West

C. cornu Ehrenb. var. *javanicum* Gutwinzki

C. cynthia De Not.

C. dianae Ehrenb.

C. dianae Ehrenb. var. *arcuatum* (Breb.) Raben.

C. dianae Ehrenb. var. *crassum* Hinode

C. dianae Ehrenb. var. *minus* Wille

C. ehrenbergii Menegh.

C. ehrenbergii Menegh. var. *ehrenbergii* fa.

C. ehrenbergii Menegh. var. *malinvernianum* (De Not.) Raben.

C. gracile Breb.

C. gracile Breb. var. *tenue* (Lemm.) West and West

C. Kolhapurense Kamat

C. Kuetzingii Breb.

C. leibleinii Kuetz.

C. navicula (Breb.) Lutkm.

C. prichardianum Arch

C. pronum Breb. var. *brevius* West fa. *sigmoideum* Woronich

C. pseudolunula Borge

C. tumidum Johnson

C. venus Kuetz.

C. venus Kuetz. var *crassa* Croasdale

Closterium sp.

Pleurotaenium baculoides (Roy and Biss.) Play-fair

P. elatum (Turner) Borge

P. ehrenbergii (Breb.) De Bary

P.ehrenbergii (Breb.) De Bery fa. nov

P. ehrebergii (Breb.) De Bary var. *curtum* Krieger

P. ovatum. Nordst. var. *inermius* Moebius

P. subcoronulatum (Turner) West and West fa. Scott and Prescott.

P. trabecula (Ehrenb.) Naegeli

P. trabecula (Ehrenb.) Naegeli var. *hirsutum* (Bail.) Krieger

P. trabecula (Ehrenb.) Naegeli var. *maximum* (Reinsch) Roll.

P. trabecula (Ehrenb.) Naegeli var. nov.

P. wallichianum (Turner) Krieger fa. *elongatum* Bicudo

Triplastrum spinulosum (Kisseler) Gouthier-Lievre

Euastrum ansatum Ehrenb.var. *triparum* Krieger

E. binale (Turp,) Ehrenb.

E. ceylanicum (West and West) Krieger

E. divergense Joshua var. *ornatum* Schm.

E. elegans (Breb.) Kuetz.

E. insulare (Wittr.) Roy fa. nov.

E. irregulare (Gonzalves and Gangla

E. róstratrum Ralfs

E. spinulosum Delp.

E. substellatum Nordst. fa.

Micrasterias foliacea Bailey

M. pinnatifida (Kuetz.) Ralfs

M. thomasiana Arch. var. notata (Nordst.) Gronblad

Actinotaenium cucurbita (Breb.) Teiling

A. cucurbita (Breb.) Teiling var. attenuatum (West) Teiling

A. diplosporum (Lund.) Teiling

A. elongatum (Racib.) Teiling var. lanceolatum (Turn.) Teiling

A. globosum (Bulnh.) Teiling

A. turgidum (Breb.) Teiling

Cosmarium beatum West and West

C. beatum West and West var. nov.

C. bengalense Turner

C. bengalense Turner fa. nov.

C. bioculatum Breb.

C. blyttii Wille

C. blyttii Wille var. nov.1

C. blyttii Wille var. Nov. 2

C. contractum Kirchner

C. contractum Kirch. var. ellipsoideum (Elfv.) West and West

C. cyclicum Lund.

C. cyclicum Lund. var. nov.

C. divergense Krieger

C. divergense Krieger var. nov.

C. gonioides West and West

C. granatum Breb.

C. granatum Breb. var pyramidale schmidle.

C. humile (Gray) Nordst.

C. humile (Gray) Nordst. fa. nov

C. impressulum Elfv.

C. impressulum Elfv. var. crenulatum (Naeg.) Krieger and Gerloff

C. impressulum Elfv. var. incrassatum Hinode

C. impressulum Elfv. var. *suborthogonum* (Racib.) West and West

C. javanicum Nordst

C. lundellii Delp. var. *circulare* (Reinsch) Krieger

C. lundellii Delp. var. *corruptum* (Turner) West and West

C. lundellii Delp. var. *ellipticum* West and West

C. monilliferum Nordst.

C. mansangense West and West

C. margaritatum (Lund.) Roy and Biswas

C. medioscrobiculatum West and West var. *agranulatum* Gutw.

C. meneghinii Breb.

C. moniliforme (Turp.) Ralfs

C. moniliforme (Turp.) Ralfs var. *limneticum* West and West

C. norimbergense Reinsch fa. *depressum* West and West

C. obtusatum Schmidle

C. panduriforme Turner

C. paradoxum Turner

C. perfissum West

C. platydesmium (Nordst.) Nordst and Sehmi

C. plicatum Reinsch

C. phaseolus Breb.

C. phaseolus Breb. var. *elevatum* Nordst.

C. phaseolus Breb. var. *minutum* (Biswas) Krieger and Gerloff.

C. portianum Arch.

C. pseudobroomei Wolle

C. pseudoexiguum Racib.

C. pseudophaseolus Bruhl and Biswas

C. punctulatum Breb.

C. punctulatum Breb. var. *subpunctulatum* (Nordst.) Borg.

C. quadratulum (Gay) De Toni var. *aplanatum* Insam and Krieger

C. regnellii Wille var. *chondrophorum* Skuja

C. regnellii Wille fa. nov

C. regnessii Reinsch

C. reniforme (Ralfs) Arch.

C. scabrum Burn

C. sexangulare Lund.

C. sinostegos Schaarschm. var. *obtusius* Gitw.

C. speciosum Lund. var. *rostafinskii* (Gutw.) West and West fa. *minus* Croasdale

C. subcostatum Nordst.

C. sublaterundatum West and West

C. submamillatum West and West

C. submamillatum West and West var. *rectangulare* Asoka Kumar

C. subspeciosum Nordst.

C. subtumidum Nordst.

C. tetragonum West and West var. *tatricum* (Racib) Krieger

C. trilobulatum Reinsch. var. *bioculatum* Krieger

C. variolatum Lund.

C. wittrockii Lund.

C. zonatum Lund.

Staurodesmus convergens (Ehrenb.) Teiling

S. convergens (Ehrenb.) Teiling var. *curtus* (Turner) Teiling

S. dejectus (Breb.) Teiling

S. leptodermus var. *corniculatum* (Lund.) Thomasson

S. subulatus (Kuetz.) Thomasson

Staurastrum disputatum West and West

S. excavatum West and West

S. excavatum West and West var. *minimum* Bernard

S. furcatum (Ehrenb.) Breb.

S. hexacerum (Ehrenb.) Wittr.

S. muticum Breb.

S. orbiculare Ralfs

S. orbiculare Ralfs var. *depressum* Roy and Biss.

S. pseudotetracerum (Nordst.) West and West

S. punctulatum Breb.

S. quadrangulare (Breb.) Ralfs
S. retusum Turner var. nitidulum Hinodi
S. sebaldi Reinsch
S. setigerum cleve
S. tetracerum Ralfs
S. tetracerum Ralfs var. cameloides Florin
S. tohopekaligense Wolle
Staurastrum sp.
Sphaerozosma excavatum Ralfs
S. granulatum Roy and Biss.
Spondylosium moniliforme Lund.
S. pulchrum (Bail.) Arch.
Hyalotheca dissillens (Sm.) Breb. var. tatrica Racib.
H. mucosa (Dillw.) Ehrenb.
Desmidium baileyi (Ralfs) Nordst.
D. pseudostreptonema West and West
D. swartzii Agardh

Order - Charales

Nitella hyalina (De Cond.) Agardh
Chara braunii
C. corollina Willdenow
C. vulgaris Linn.
C. zeylanica Willdenow

Division-- Euglenophyta
Class - Euglenophyceae
Order - Euglenales

Euglena gracilis Klebs
E. oxyuris Schmarda var. minor Prescott
E. proxima Dang.
E. spirogyra Ehrenb.
Lepocinclis ovum (Ehrenb.) Lemm.
Phacus carvicauda Swirenko

P. lemmermannii (Swir.) Skvortzou.

P. nordstedtii Lemm.

P. orbicularis Huebrier

P. tortus (Lemm.) Skvortzou

Trachelomonas acanthostome (Stokes) Deflander

T. armata (Ehrenb.) Stein var. longispina (Playf.) Deflander

T. hispida (Perty)Stein var. coronata Lemm.

T. Playfairii Deflander

T. pulcherrima Playfair var. minor Playfair

T. robusta Swirenko

T. superba (Swir.) Deflander

T. superba (Swir.) Deflander var. nov.

T. sydnensis playfair var. nov.

T. volvocina Ehrebb.

T. volvocina Ehrenb. var. punctata Playfair

T. volvocina Ehrenb. var. compressa

Division - Chrysophyta

Class - Xanthophyceae

Order - Rhizochloridales

Gloeobotrys limneticus (Smith) Pascher

Characiopsis longipes (Rabenb.) Borzi

Ophiocytium arbuscula (A Braun) Rabenh.)

O. parvulum (Perty) A. Braun

Class - Chrysophyceae

Order - Chrysomonadales

Mallomonas acaroides Perty

Dinobryon sertularis Ehrenb.

Class - Bacillariophyceae

Order - Centrales

Melosira granulata (Ehrenb.) Ralfs

M. granulata (Ehrenb.) Relfs var. angustiasima O. Mull.

Cyclotella meneghiniana Kuetz.

Order - Pennales

Fragilaria capuciana Desmaz. var. *courtellensis* Krishna Murthy

Synedra ulna (Nitz.) Ehrenb.

Eunotia pectinalis (Kuetz.) Rabenh.

E. pectinalis (Kuetz.) Ratenh. var. *gibulosus*

Achanthes microcephala Kuetz.

Cocconeis placentula Ehrenb. var. *euglypta* (Ehrenb.) Cleve

C. placentula Ehrenb. var. *lineata* (Ehrenb.) Clave

Navicula bryophila Boye Pet

N. cari Ehrenb.

N. cryptocephala Kuretz. var. *veneta* (Kuetz.) Grun.

N. cuspidata Kuetz. var. *ambigua* Ehrenb.

N. halophila (Grun.) cleve fa. *subcapitata* Ostrup

N. haste Pantocsek

N. viridula Kuetz.

Pinnularia brebissonii (Kuetz.) fa. *producta* A.cl.

P. borealis Ehrenb.

P. gibba Ehrenb.

P. interrupta Smith

Diploneis elliptica (Kuetz.)

Amphipleura pellucida Kuetz.

Pleurosigma angulatum (Quekett) Smith fa. *chemburiana* Gandhi

Mastogloia smithii thwaites var. *lacustris* Grun.

Gomphonema aequatoriale Hust.

G. augur Ehrenb. var. *genninum* Mayer

G. intricatum Kuetz. var. *vibrio* (Ehrenb.) Cleve

G. parvulum (Kuetz.) Grun.

G, subapicatum Fritsch and Rich

Gomphonema sp.

Cymbella affinis Kuetz.

C. cymbiformis (Ag.) Kuetz. var. *nerei* (Prant) cleve

C. tumida (Breb.) V.H.

Amphora acutiuscula Kuetz.

A. ovalis Kuetz.

Epithemia sorex Kuetz.

E. zebra (Ehrent.) Kuetz. var. *Saxanica* (Kuetz.) Grun

Rhopalodia gibba (Ehrenb.) Mull.

Nitzschia closterium (Ehrenb.) Smith

N. fonticola Grun

N. obtusa Smith var. *scalpelliformis* Grun.

N. recta Hantz.

Hantzschia amphioxys (Ehrenb.) Grun. var. *vivax* (Hantz.)Grun.

Surirella linearis Smith

S. robusta Ehrenb.

Division - pyrrophyta
Class - Dinophyceae
Order - Peridiniales

Peridinium inconspicuum Lemm.

Division - cyanophyta
Order - Chroococcales

Microcystis aeruginosa Kuetz.

M. elongata Desikachary

M. flosaquae (Wittr.) Kirchner

M. protocystis Crow

M. pseudofilamentosa Crow

M. viridis (Braun) Lemm.

Chroococcus limneticum Lemm.

C. minor (Kuetz.) Naegeli

C. minutes (Kuetz.) Naegeli

Aphanocapsa biformis Braun

Aphanothece pallida (Kuetz.) Rabenb.

Gomphosphaeria aponica Kuetz.

G. lacustris Chodat var. *compacta* Lemm.

Merismopedia elegans Braun

M. punctata Meyen

M. tenuissima Leem.

Daetylococcopsis raphidioides Hansg.

Order - Chaemosiphonales

Stichosiphon sansibaricus (Hieron.) Drouetet

Order - Oscillatoriales

Arthrospira jenneri Stizenb. Gomot

Spirulina major Kuetz. ex Gomot

Oscillatoria amphigranulata Vangoor

O. animalis Ag. ex Gomet fa. *tenuior* Stockm.

O. curviceps Ag. ex. Gomot var. *angusta* Chose

O. grunowians Gomont

O. jasorvensis Vouk

O. laete-virens (Grouan)Gomont

O. laete-virens (Grouan) Gomont var. *minimus* Biswas

O. limosa Ag. ex Gomont

O. nigra Vaucher

O. princeps Vaucher ex Gomont

O. proboscidea Gomont

O. salina Biswas fa. *major* Desikachary

O. subbrevis Schmidle

Phormidium bohneri Schmidle

P. subincrustatum Fristch and Rich

Lyngbya hieronvenusii Lemm.

L. magnifica Gardner

Anabaenopsis arnoldii Aptekarj

Cylindrospermum indicum Rao

Nostoc microscopicum Carm. ex. Born. et Flah.

N. sphaericum Vaucher ex Born. et Flah.

Anabaena circinalis Rabenh.

A. flos-aquae (Lyngl.) Breb. ex Born. et Flah.

A. oscillarioides Bory ex Born. et Flah.

A. sphaerica Born. et Flah. var. *attenuata* Bharaduraja

Raphidiopsis mediterranea Skuja

Aulosira fritschii Bharadwaja

Scytonema chiastum Geitler

S. coactile Mont. ex Born. et Flah.

Tolypothrix nodosa Bharadwaja

Calothrix castellii (Massal.) Born. et Flah. var.
    samastipurense Rao

Rivularia aquatica De Wilde

R. dura Roth ex Born. et Flah.

Gloeotrichia Kurziana Zeller

G. raciborskii Voloszynska

G. raciborskii Volszy. var. Kashiense Rao

The percentage composition of various divisions of algae in the two lakes are given below:

UPPER LAKE

	1979-80		1980-81	
Division	Number of taxa	Percentage	Number of taxa	Percentage
Chlorophyta	221	69.28	271	71.51
Euglenophyta	9	2.82	20	5.27
Chrysophyta	43	13.48	41	10.82
Pyrrophyta	1	0.31	1	0.26
Cyanophyta	45	14.11	46	12.14
Total no. of taxa	319	Total no. of taxa	379	

LOWER LAKE

Division	1979-80 Number of taxa	1979-80 Percentage	1980-81 Number of taxa	1980-81 Percentage
Chlorophyta	142	62.84	146	66.37
Euglenophyta	15	6.64	13	5.91
Chrysophyta	38	16.81	35	15.91
Cyanophyta	31	13.71	26	11.81
	Total no. of taxa: 226		total no. of taxa : 220	

The year-wise distribution of the number of algae in each lake is given in table 10. The principal component of the algal flora of Upper Lake was found to be Chlorophyta with maximum number of desmids (35%) and Chlorococcales (23%). The members of Chlorophyta were dominant in Lower Lake also, but Chlorococcales (36.3%) were higher in number of taxa than desmids (19%). The monthly, seasonal and year-wise occurrence, distribution and abundance of algae in Upper Lake and Lower Lake have been studied in detail.

Ten genera of Volvocales each with one species were noted during the entire period of study. Seven species were observed from Lower Lake. A minimum number of three species was recofded during monsoon of 1980-81. Only five species were observed in Upper Lake. Their occurrence was rare. Only Volvox mononae was very common in winter. It was a rare form in summer and did not occur in monsoon and post-monsoon. Species of Chlamydomonas, Cocomonas, Pteromonas, Gonium and Eudorina were absent in this water body while Dysmorphococcus, Pleudorina and Volvox were absent in the Lower Lake.

Table 10

The year-wise distribution of the number of algal taxa in Upper Lake and Lower Lake

ALGAE	Upper Lake		Lower Lake	
	1979-80	1980-81	1979-80	1980-81
CHLOROPHYTA				
Volvocales	5	4	3	7
Tetrasporales	4	2	3	4
Ulotrichales	3	4	5	5
Chaetophorales	8	10	2	3
Ulvales	-	1	-	-
Oedogoniales	5	11	1	-
Cladophorales	2	2	4	3
Chlorococcales	72	86	80	82
Zygnematales				
Zygnemataceae	10	12	1	1
Mesotaeniaceae and Desmidiaceae	107	132	43	41
Total	221	271	182	146
EUGLENOPHYTA				
Euglenales	9	20	15	13
Total	9	20	15	13
CHRYSOPHYTA				
Rhizocloridales	1	1	1	1
Chrysomonadales	1	2	1	1
Centrales	4	3	3	3
Pennales	37	36	34	30
Total	43	41	38	35

ALGAE	Upper Lake		Lower Lake	
	1979-80	1980-81	1979-80	1980-81
PYRROPHYTA				
Peridiniales	1	1	-	-
Total	1	1	-	-
CYANOPHYTA				
Chroococcales	15	17	11	11
Chaemosiphonales	-	-	1	-
Oscillatoriales	30	29	19	15
Total	45	46	31	26

Tetrasporales were altogether a rare group with five species belonging to four genera. In Lower Lake these forms by and large were observed during summer and winter seasons only. *Palmella mucosa* was noted only once, in the summer of 1979-80. Out of the five species of this order, four were found to occur in winter season. In the Upper Lake *Sphaerocystis schroeteri* occurred during winter season, remaining forms were rare. Here again, *P. mucosa* was found to be a rare summer form while *Asterococcus limneticus*, though rare, occurred during summer and monsoon seasons. *Gloeocystis ampla* and *G. gigas* were found only in the winter of 1980-81 in the lower lake while the former was recorded in summer only in upper lake, where the latter was altogether absent.

Four species belonging to two genera of Ulotrichales were reported from Lower Lake. During the first year of study *Uronema africanum* was very common in post-monsoon.

In the second year all the four species were recorded in all the seasons. However, *Geminella*, *Cylindrocapsa* and *Pearsoniella* were absent. Collections from the Upper Lake did not show *Uronema africanum* and *U. confervicolum* but *G. interrupta* was the most common species in summer 1980 and *P. variabilis* was recorded once in January 1981. Out of the three species of *Ulothrix* only *U. moniliformis* was found to be a common form occurring in all the seasons.

There were 12 species of Chaetophorales growing in Upper Lake in the post-monsoon, winter and summer seasons. *Chaetosphaeridium globosum* was occurring in winter and summer seasons only. Most of the species of this order were common to very common but *Protococcus viridis* was a rare one found only in winter of 1980-81. The pattern of distribution of the members of this group in Lower Lake is very interesting. Only three species of *stigeoclonium* were present of which *S. flagelliferum* was collected only in summer. *S. polymorpha* occurred in all the seasons except summer. *Coleochaete* was one of the most prominent genera with 6 species which were common in Upper Lake. But it was totally absent in Lower Lake. *Schizomeris leibleinii*, a member of Ulvales was notable by its presence only in this lake making its appearance in monsoon.

Oedogoniales with ten species of *Oedogonium* and one of *Bulbochaete* have a fair distribution in the Upper Lake in almost all the seasons. *Bulbochaete reticulata* was however, not found in the summer. These were abundant in the monsoon season of the year 1980-81. *O. patulum* was the only species found in the Lower Lake. It was present during monsoon.

Cladophorales constitute a small group of two genera, *Cladophora* and *Rhizoclonium* with four taxa. All of them were common to very common in Lower Lake except during monsoon. *R. hieroglyphicum* var. *hosfordii* was noted only in winter and summer of 1979-80. The genus Cladophora was conspicuous by its absence in Upper Lake while *Rhizoclonium* occurred in all the seasons except monsoon.

Chlorococcales is one of the largest groups of algae found in these lakes. A total of 134 species belonging to 35 genera have been found. 108 tada of 28 genera were present in the Lower Lake and 39 taxa of 25 genera were present in the Upper Lake. *Rhopalosolen*, *Characium*, *Schroderia*, *Micractinium*, *Golenkinia*, *Chodatella*, *Actinastrum*, *Tetrastrum*, *Myrmecia* and *Tetradesmus* were found exclusively in Lower Lake and *Sorastrum*, *Gloeotaenium*, *Dimorphococcus*, *Kircheneriella*, *Tetrallantos*, *Elakatothrix* and *Radiococcus* were found exclusively in Upper Lake. *Schroederia*, *Actinastrum*, *Sorastrum* and *Kircheneriella* were occurring in all the seasons whereas, *Tetrastrum*, *Myrmecia* and *Tetradesmus* were recorded in monsoon season only. *Elakatothrix* and *Radiococcus* were observed once during summer and post-monsoon respectively. *Characium* occurred during all the seasons of both the years except winter, *Gloeotaenium* except monsoon and *Dimorphococcus* except summer season. *Rhopalosolen* a rare genus was noted during monsoon and post-monsoon, *Chodatella* during monsoon and winter and *Tetrallantos* during post-monsoon and winter. *Tetraedron* though present in Upper Lake during all the seasons, was very common to abundant in summer. In Lower Lake it was common during monsoon but the maximum number of species was recorded during winter of 1979-80. *Closteridium siamensis* was recorded from both the lakes during the monsoon of 1980 while, all the three species of the genus were recorded from Upper Lake in winter of 1980-81. *Oocystis* with its six species has a fair distribution throughout the seasons in the Upper Lake, though they were not abundant in number. In Lower Lake except *O. irregularis* and *O. gigas f. monor* which were not represented at all, the genus was found to be of rare occurrence. *Nephrocytium agardhianum* was the only species present rarely in this lake in winter and post-monsoon but in addition to this *N. lunatum* and *N. obesum* were present in the other lake. *Ankistrodesmus* present in all the seasons was common and *A. falcatus* was one of the most commonly distributed species. *A. falcatus* var. *radiatus* was absent in Upper Lake. Out of the five species of *Coelastrum* four were present in both the lakes and fifth, a new species was present in Upper Lake.

Scenedesmus is a genus of *Chlorococcales* with the largest number of species and individuals which can best be considered as one of the most common genera. It was fairly distributed in these lakes in almost all the seasons. *S. bijugatus* var. *alternans*, *S. bijugatus* var. *graevenitzii*, *S. brasiliensis*, *S. denticulatus*, *S. dimorphus* and *S. platydiscus* were present during all the four seasons, while *S. abundans* and *S. obliquus* were common in Lower Lake. *S. abundans* var. *brevicauda* fa. nov., *S. armatus* var. nov., *S. quadricauda* fa. nov. were most rare forms and recorded only once during the study from Upper Lake. *S. abundans* var. *brevicauda* fa. nov., *S. abundans* var. *hyperabundans*, *S. abundans* var. *skujae*, *S. hystrix* var. nov. and *S. platydiscu* var. nov. were recorded once from Lower Lake. Out of the four genera of *Zygnemaceae*, *Mougeotia Zygnema* and *Zygnemopsis* were not recorded from Lower Lake. *Spirogyra* was represented by two species *S. elliptica* and *S. inflata*, the latter was collected in summer 1980-81. All the 12 species of this family were found to grow in the Upper Lake. These were collected in large numbers in reproductive stage mostly in winter and summer.

Except *Gonatozygon monotaenium* none of the species of the genus occurred in the Lower Lake. It was a rare form and was collected in summer. In Upper Lake all the species of this genus were present in all the seasons. But *G. aculeatum* was found only in post-monsoon and winter seasons. The genus *Netrium* was represented here by a single species, which was observed in monsoon. *Penium cylindrus* was collected only once in summer from Lower Lake and in winter from Upper Lake. *Closterium* is a widely distributed genus occurring in these two lakes, having a good number of species during all the seasons. The Upper Lake has a wide representation of this genus. *C. dianae* var. *minus*, *C. leibleinii* and *C. venus* occurring in the post-monsoon season and *C. lineatum* found in summer are some of the rare forms while *C. ehrenbergii* and *C. prichardianum* are the most common forms having distribution in all the seasons in Lower Lake. Some of the rare taxa like *C. acerosum*, *C. cornus* var. *javanicum*, *C. cynthia* occurred in Upper Lake during winter. *C. aciculare*, *C. kolhapurense* in summer and *C. navicula* in monsoon, *C. dianae*, *C. pronum* var. *brevius* fa. *sigmoideum*, *C. ehrenbergii* and *C. prichardianum* occurred in all the seasons. *C. leibleinii* and *C. lineatum* were found only in Lower Lake, another 14 taxa were exclusively found in Upper Lake. The maximum number of species occurred in both the lakes during winter and summer.

Out of 12 species of *Pleurotaenium* only *P. ehrenbergii* var. *curtum* was recorded from Lower Lake. This was in winter season. All the 12 species were noted in Upper Lake during post-monsoon and winter seasons and were not recorded during monsoon and summer seasons. *Triplastrum spinulosum* was found in Upper Lake only during all the seasons. *Euastrum* was frequently observed in Upper Lake but very sparse in the other. *Micrasterias* did not occur in the latter but was fairly distributed in the former, except in summer. *Micrasterias thomasiana* was a rare form which was seen once in January 1981. Six taxa of *Actinotaenium* were recorded out of which 5 were noted in Upper Lake during all the seasons except post-monsoon while only one taxa *A. elongatum* var. *lanceolatum* was recorded from Lower Lake during post-monsson and summer seasons. Seventy one species of *Cosmarium* have been noted from both the lakes. This is the largest single genus which as a whole occurs round the year and has a maximum number of species and individuals occurring in Upper Lake rather than in Lower Lake during the two years of study. *C. phaseolus* var. *elevatum* was exclusive to Lower Lake. Forty three taxa were exclusive to Upper Lake. The maximum number of species and individuals in this lake was in winter and minimum in summer. While in the other, maximum was in winter and minimum in post-monsoon season. *C. beatum*, *C. blyttii* var. nov. 1, *C. blyttii* var. nov. 2, *C. lundellii* var. *ellipticum*, *C. panduriforme*, *C. pseudobroomei*, *C. regnellii* fa. nov., *C. subcostatum*, *C. tetragonum* var. *tatricum* and *C. wittrockii* were rare forms but *C. tetragonum* var. *tatricum* and *C. javanicum* were most common forms and observed throughout the seasons in Lower Lake. Similarly, in Upper Lake *C. bengalense*, f. nov *C. cyclicum* var. nov., *C. divergens* var. nov., *C. gonioides*, *C. impressulum* var. *crenulatum*, *C. lundellii* var. *ellipticum*, *C. platydesmium* and *C. scabrum* were rare forms, while *C. divergense*, *C. humile*, *C. lundellii* var. *circulare*, *C. portianu* *C. reniforme*, *C. submamillatum* var. *rectangulare* and *C. wittrockii* were found to be most common taxa. *Staurodesmus* was recorded from Upper Lake only. *S. leptodermus* var. *corniculatus* and *S. subulatus* were most rare forms, though *St. dejectus* was recorded in all the seasons. *Staurastum* was represented by 18 taxa out of these 11 were present exclusively in Upper Lake. *S. pseudotetracerum* was rare form and noted during winter and summer. *S. tetracerum* var. *cameloides* also a rare form noted during monsoon and winter. *S. excavatum* var. *minimum*, *S. muticum*, *S. punctulatum* and *S. tetracerum* were most common taxa and were noted during all the seasons. In Lower Lake only 7 species were noted. They were sparsely distributed.

Sphaerozosma, *Spondylosum*, *Hyalotheca* and *Desmidium* were observed in Upper Lake during all the seasons and frequently occurred in post-monsoon and winter. From Lower Lake only one species of sphaerozosma i.e. *Sphaerozosma granulatum* was recorded in summer season only. *Nitella* and *Chara* were recorded from Upper Lake only and were found in almost all the seasons except when the temperature was too high.

In the year 1979-80 number of taxa of Chlorophyta in Upper Lake showed a marked variation. Highest number of taxa was observed during January, 1980 in winter season with 110 taxa, which was followed by November, 1979 in post-monsoon and September, 1979 in monsoon season with 80 and 77 taxa respectively. Only 38 taxa were recorded during October,1979.

In 1980-81 highest number was observed in January, 1981 during winter season with 119 taxa followed by October, 1980 in post-monsoon and July,1980 in monsoon with 102 and 77 taxa respectively. The largest number of taxa belonged to Desmids and Chlorococcales, which followed the same trend of fluctuation as shown by the division Chlorophyta as a whole.

Considering both the years together, according to the order of dominance the genus *Cosmarium* is the most dominant form. The next 5 genera in order of dominance were *Scenedesmus*, *Closterium*, *Staurastum*, *Tetraedron* and *Pleurotaenium*.

In Lower Lake there were four clear cut maxima. In 1979-80 highest number of 69 taxa were observed in January 1980 in winter season, followed by March 1980 in summer, November 1979 in post-monsoon and September 1979 in monsoon with 48, 46 and 28 respectively. Minimum number of taxa was recorded in October 1979 with 12. But in the year 1980-81 highest number of taxa was found in July and September 1980 in monsoon season with 61 and 51 taxa respectively, second peak was in January 1981 in winter, third in March 1981 in summer and fourth in November 1980 in post-monsoon with 43, 41 and 40 taxa respectively. Minimum number was recorded in April 1981 in summer season with 27 taxa.

Chlorococcales were highest in number and showed the same trend of fluctuations as Chlorophyta as a whole. Desmids formed the second largest group but did not show any significant seasonal peak, though they occurred in good numbers in winter, summer and monsoon.

The order of highest number of species of genera, during the period of study were *Scenedesmus*, *Commarium*, *Occystis* and *Characium*.

Euglena gracilis was found throughout the course of investigation in both the lakes. During first year *Euglena oxyuris* var. *minor* was frequently occurring in Lower Lake, while it was not recorded from the other. In Second year in Upper Lake it was observed during post-monsoon and in Lower Lake it was not seen during monsoon and post-monsoon seasons. *Euglena proxima* was frequent in occurrence in both the lakes. *Euglena spirogyra* was common in Lower Lake and sparse in Upper Lake, where *Lepocinclis ovum* was not recorded during first year. In the second year it was found in post monsoon and winter seasons. In Lower Lake *Lepocinclis ovum* was recorded once every year during summer season. In Upper Lake during first year *Phacus* was noted as a very rare form and during second year it did occur quite frequently. *Trachelomonas hispida* var. *coronata*, *T. volvocina* were recorded throughout the seasons except post-monsoon of first year from Upper Lake. *T. acanthostoma* was observed once in August 1979 from Upper Lake. *Phacus curvicauda* and *Trachelomonas valvocina* was recorded throughout the seasons from Lower Lake.

In Upper Lake in the year 1979-80 highest number of taxa of Euglenophyta was occurring in the month of August 1979 in monsoon season with 5 taxa, followed by a further maxima recorded in the month of October 1979 in post-monsoon and March 1980 in summer, each with 4 taxa. A minimum was recorded in November 1979 in post-monsoon with only one taxon. But in the year 1980-81 highest number of 11 taxa was observed in June 1980 in monsoon, followed by a further maxima in January 1981 in winter, October 1980 in post-monsoon and April 1981 in summer with 10, 9 and 7 taxa respectively. A minimum number of one taxon was recorded in March 1981 in summer. In Upper Lake Euglenophyta in order of dominance of genera were *Trachelomonas*, *Phacus*, *Euglena* and *Lepocinclis*.

In Lower Lake in the year 1979-80 maxima was recorded in March 1980, August 1979, in which highest was in March 1980 in summer season with 11 taxa. A minimum number was found in October 1979 with one taxon. In the year 1980-81 maxima were recorded in March, 1981, June and July 1980 in which 9 taxa were recorded in March 1981 in summer season. Minimum number was recorded in December 1980 in winter season with only one taxon. *Trachelomonas* was highest in number of species than *phacus*, *Euglena* and *Lepocinclis*. Rhizocloridales and Chrysomonadales rarely occurred during both the years in both the lakes. *Dinobryon sertularia* was an exception which was found commonly during winter season of both the years in Upper Lake.

Melosira granulata var. *muzzanensis* was a very rare form and recorded once in August 1979 from Upper Lake. *Cyclotella meneghiniana* was very abundant in the month of November 1979 and February 1981 in Lower Lake. In Upper Lake *Cymbella affinis* occurred during all the seasons but was abundant during January and February 1980. *Epithemia zebra* var. *saxonica* was also recorded throughout the seasons and it was abundant during post-monsoon, winter and summer of the first year. *Surirella linearis* and *S. robusta* were recorded from Upper Lake only. In Lower Lake only. In Lower Lake *Fragilaria capuciana* var. *courtallensis*, *Synedra ulna* were recorded throughout the period of investigation. *Synedra ulna* was very common in January,1980. *Pleurosigma angulatus* fa. *chemburiana* was a rare form recorded exclusively from Lower Lake.

Chrysophyta showed only one maxima in Upper Lake in the monsoon season. In 1979- 80 highest number of 30 taxa was found in August 1979 in monsoon. In winter the number was constant and it recorded a slight fall in summer. Minimum number of 12 taxa was recorded in October in post-monsoon.

In the year 1980-81 highest number was recorded in July 1980 in monsoon with 32 taxa. In winter there was no change in the number of taxa and in summer it showed a marked decrease. Minimum number was observed in May 1981 in summer with 12 taxa. The order of dominance was *Navicula*, *Gomphonema*, *Nitzschia*, *Cymbella* and *Molosira*.

In Lower Lake in 1979-80 highest number was recorded in the month of October and November in post-monsoon with 24 taxa and lowest in April 1980 in summer season with 10 taxa. In the year 1980-81 maximum number was recorded in July, 1980 in monsoon with 23 taxa and minimum in April, 1981 in summer season with 11 taxa. In order of dominance *Navicula*, *Gomphonema*, *Nitzschia*, *Cymbella* were recorded.

Only one species of Pyrrophyta has been recorded from Upper Lake. This was not observed in Lower Lake.

Microcystis frequently occurred in both the lakes. *M. aeruginosa* was recorded in all the seasons. It was common during monsoon, post-monsoon and winter season as compared to summer. *Gomphosphaeria* and *Merismophedia* were much frequent in Upper Lake than in Lower Lake. *Gomphosphaeria lacustris* var. *compacta* was abundant during winter of the first year. *Merismopedia tenuissima* was abundant during May 1980. *Stichosiphon sansibaricus* was present during post-monsoon and winter of first year in Lower Lake. *Arthrospira jenneri* was seen once in November, 1979. Similarly, *Aulosira fritschii* was also recorded once in January, 1980. Out of the thirteen species of *Oacillatoria*, *O. subbrevis* *O. nigra* and *O. animalis* fa. *tenuior* were rare forms in Lower Lake occurring in winter and monsoon seasons. As in

Upper Lake most of the species were common and present in all the seasons, *Gloectrichia* occurred abundantly during winter and summer of 1980-81 in Upper Lake. It was not recorded from Lower Lake.

In Upper Lake there were two distinct peaks for Cyanophyta. In 1979-80 highest peak was recorded in November, 1979 in post-monsoon with 21 taxa. A second peak was observed in April, 1980 in summer with 20 taxa. Minimum number was recorded in July and August in monsoon with 11 taxa. But in the year 1980-81 highest peak was in September and October, 1980 in monsoon and post-monsoon respectively with 21 taxa. A second peak was in May, 1981 in summer. Sequence of order of dominance of genera was *Oscillatoria*, *Microcystis*, *Anabaena* and *Merismopedia*.

In Lower Lake in the year 1979-80 two peaks were recorded. Highest peak was in November, 1979 in post-monsoon and second in March, 1980 in summer with 13 and 12 taxa respectively. Minimum number was recorded in February, 1980 in winter with one species. While in the year 1980-81 highest peak was in June 1980 in monsoon and second peak was in March 1981 in summer each with 10 taxa. Lowest number was recorded in November 1980 in post-monsoon. *Oscillatoria* was the most dominant genus followed by *Microcystis*, *Lyngbya* and *Merismopedia*.

Both the water bodies under investigation have quite different values of physico-chemical characteristics of water. Although, there was no considerable difference in temperature and pH of both the lakes, Lower Lake showed appreciably highest values of dissolved oxygen, total alkalinity, calcium hardness, chloride, nitrate, nitrite and phosphate. These factors as a rule did not show much

marked ans specific pattern of variations according to different seasons. This lake especially with higher amount of nutrients accounted for lesser number of algal species but higher number of individuals as against the Upper Lake where the values of these factors were considerably less but showed maximum number of species. Seasonal variation of those factors were more prominent in this lake and therefore, it was possible to establish definite correlation among themselves and these with the various groups of algae.
It has been observed that a number of aquatic fungi were parasitic on the members of Oedogoniales, Zygnemetales and charales. Most prominent of them were _Oedogenium_, _cosmarium_, _spirogyra_, _Zygnema_ and _chara_.

Aquatic Fungi

A total number of 22 genera and 42 species of aquatic fungi have been isolated from both the lakes during the course of the present study. Out of which one species of _Achlya_ is considered as new to science, while twelve fungal forms are reported for the first time from India. These fungi belong various orders of the group Phycomycetes. The number of fungal species corresponding to each order as occurred in both the lakes are given below:-

Chytridiales	... 8
Blastocladiales	... 3
Saprolengniales	...23
Lagenidiales	... 2
Peronosporales	... 6

Members of the saprolengniales were dominant over the rest of the orders of aquatic fungi, in both the lakes.

It was found out that Upper Lake had a richer fungal flora as compared to that of the Lower Lake. The study of fungal flora of Upper Lake revealed the occurrence of 22 genera and 35 species belonging to the following orders:-

Chytridiales	...	8
Blastocladiales	...	3
Saprolengniales	...	17
Lagenidiales	...	2
Peronosporales	...	5

Similarly, from the Lower Lake 13 genera and 26 species of Phycomycetes have been isolated. Their number is given below:-

Chytridiales	...	4
Blastocladiales	...	1
Saprolegniales	...	15
Lagenidiales	...	1
Peronosporales	...	5

Some species were confined to only one lake.

Following species were exclusively found in Upper Lake:-

Olpidium utriculiforme scherffel

Rhizophydium carpophilum (Zopf) Fischer

Diplophyctis intestina (Schenk) Schroeter

Blastocladiella navae-Zeylandiae Karling

Blastocladia sparrowii Indoh

Leptolegnia sp.

Protoachlya paradoxa Coker

Achlya apiculata de Bary

A. *imperfecta* Coker

A. *megasperma* Humphrey

A. *oblongata* de Bary

A. *oligacantha* de Bary

A. proliferiodes Coker

Lagenidium pygmaeum Zopf and

Pythium aphanidermatum (Edson) Fitz.

Following species were found exclusively in Lower Lake, namely:

Saprolegnia furcata Maurizio

Achlya flagellata Coker

A. orion Coker and Couch

A prolifera (Nees) de Bary

Dictyuchus pseudoachlyoides Beneke

D. sterile Coker and

Pythium sp.

Following species were common to both the lakes:

Rhizidium sp.

Karlingia aurantiaca Karling

Blyttiomyces spinulosus (Blytt.) Bartsch

Chytridium olla Braun

Catenophyctis variabilis Karling

Saprolegnia diclina Humphrey

S. ferax (Gruith.) Thuret

Achlya conspicua Coker

A. hypogyna Coker and Pemberton

A. klebsiana Pieters

Achlya sp. nov.

Aphanomyces laevis de Bary

Aphanomyces sp.

Dictyuchus monosporus Leitgeb

Myzocytium proliferum Schenk

Pythium debaryanum Hesse

P. middletonii Sparrow

Pythiogeton ramosum Minden

Phytophthora gonapodyides (petersen) Buisman

The maximum number of fungi recorded in the year 1979-80 from Upper Lake was 12 in the month of December and January, while the minimum number was 3 in the month of May. In the year 1980-81, 15 species were found in January and only 4 in May.

During 1979-80, 15 fungal forms were recorded in January while only 4 in May, June and July from Lower Lake. A maximum of 14 species were recorded in January and minimum only 4 in May and June, 1981.

It was found that the number of fungi started increasing gradually from June onwards. This trend in the increase in number continued till August. There was a gradual decline in their number in September. The number of fungi remained almost the same in October and November followed by a sharp rise in December and January. From February to May the number again showed a gradual decline. This general trend in the fluctuation of fungi was found out in both the lakes. However, minor deflections from this course of fluctuations were also noticed.

In Upper Lake, *Aphanomyces laevis* was found to be the most dominant species with a frequency of 43.75%. *Karlingia aurantiaca* was the codominant, having a frequency of 31.25%. In Lower Lake higher percentage frequency of 30.62% was obtained for *Karlingia aurantiaca* followed by *Aphanomyces laevis* 29.16% and *Pythium debaryanum* 28.54%. The above three species were recorded from both the lakes during all the seasons. Besides these, *Sparolegnia diclina*, *S. ferax*, *Achlya* sp., *Aphanomyces* sp., *Pythium middletonii*, *P. debaryanum* and *Pythiogeton ramosum* were also recorded constantly in all the seasons.

Some species were recorded only during low temperature conditions of winter months, such as *Rhizophydium carpophilum*, *Diplophlyctis intestina*, *Rhizidium* sp., *Blastocladiella novaeylandiae*, *Leptolegnia* sp., *Achlya flagellata*, *Dictyuchus monosporus*, *D. pseudoachlyoides* and *D. sterile*.

Fungi which occurred in monsoon as well as in winter seasons had a low to moderate temperature requirement. These were: *Olpidium utriculiforme*, *Blyttiomyces spinulosus*, *Entophlyctis bulligera*, *Chytridium olla*, *Catenophlyctis variabilis*, *Blastocladia sparrowii*, *Protoachlya paradoxa*, *Achlya apiculata*, *A. conspicua*, *A. hypogyna*, *A. imperfecta*, *A. klebsiana*, *A. megasperma*, *A. oblongata*, *A. oligacantha*, *A. orion*, *A. prolifera*, *A. proliferoides* and *Lagenidium pygmaeum*.

Five species were recorded only during those months, when either moderateor high temperature conditions prevailed i.e. in post-monsoon and summer but never in winter season. These forms were *Saprolegnia furcata*, *Myzocytium proliferum*, *Pythium aphanidermatum*, *Pythium* sp., and *Phytophthora gonapodyides*.

Entophlyctis bulligera and *Blastocladiella novae-zeylandiae* were found to be very rare forms. These were reported only once during the entire course of study.

Some of the fungal forms were found parasitic on algae, aquatic angiosperms or on other aquatic fungi.

The parasitic fungi and their host plants are presented below:

Fungal parasite	Host
1. *Olpidium utriculiforme*	*Cosmarium lundelii*
2. *Rhizophydium carpophilum*	on oogonia of *Achlya hypogyna*
3. *Blyttiomyces spinulosus*	*Spirogyra elliptica*
4. *Entophlyctis bulligera*	*Spirogyra* sp.

5. *Chytridium olla*	*Oedogonium plusiosporum*
6. *Myzocytium proliferum*	*Spirogyra* sp. and *Zygnema* sp.
7. *Lagenidium pygmaeum*	*Myriophyllum* sp.

There was a specificity of bait for particular fungal form. Hempseeds were found to be the most suitable bait for the isolation of most of the Saprolegniaceous fungi. Species of *Achlya* were isolated on hempseeds and mustard seeds baits. Species of *Dictyuchus* were isolated on wheat and hempseeds, while species of *Saprolegnia* preferred ant, hempseeds and mustard seeds. *Karlingia*, *Catenophlyctis* and species of *Aphanomyces* were isolated on snake skin bait. Members of Peronosporales were isolated mostly on boiled grass leaves while *Blastocladia sparrowii* was obtained on submerged apple fruits.

CHAPTER - 5

DISCUSSION

Maximum number of species of Chlorophyta was present in the month of January in Upper Lake. The physico-chemical characters found to be responsible for this were a low winter temperature, moderate dissolved oxygen content of 8 -10mg/l, pH 8.2, total alkalinity of 76 - 114 mg/l, chloride content of 9-12 mg/l, moderate calcium hardness of 14-37 mg/l, 0.09 to 0.11 mg/l of phosphate, high values of nitrate, i.e., 0.09 to 0.11 mg/l. Nitrite was altegether absent. (Tables 1-9.)

In Lower Lake Chlorophyta showed peaks in different seasons. During first year it was recorded in January in winter when dissolved oxygen was moderate i.e., 7-9 mg/l. In the second year it was in July in monsoon when its value was 7.1 mg/l. Almost the same value of dissolved oxygen was available in January in Upper Lake. It has been found that magnitude of peaks in Lower Lake was comparatively low. This is due to higher amount of nutrients and chemically rich nature of this lake. A lower level of dissolved oxygen and consequently lesser number of species occurred in January 1981 (Tables 1-9).

In Upper Lake maximum number of Euglenophyta was recorded in monsoon during both the years. Monsoon season was characterised by higher concentration of chloride 10-15 mg/l, phosphate 0.02 to 0.11 mg/l and nitrate 0.08-0.11 mg/l, moderate values of dissolved oxygen 8-10 mg/l, temperature, calcium hardness 14-37 mg/l, alkalinity 94-122mg/l, low pH and very low nitrite. But in Lower Lake peaks were noted during summer in both the years when temperature was high, higher concentration of dissolved oxygen 7-14mg/l, total alkalinity 124- 149 mg/l, chloride 28 to 39 mg/l, pH 8-8.4, moderate amount of calcium hardness 62-77 mg/l, nitrite 0.03 -0.13 mg/l, low concentration of phosphate and nitrate 0.03 to 0.05 mg/l and 0.03 to .05 mg/l respectively. A perusal of physico-chemical characters of both the seasons of both the lakes reveals that Euglenophyta occur in large number when high quantity chloride and dissolved oxygen along with high temperature were present (Tables 1-9).

In Upper Lake Chrysophyta showed maxima in monsoon season during both the years, while in Lower Lake peaks were recorded during post-monsoon in first year and in second year during the monsoon. In Upper Lake during monsoon physico-chemical characters showed higher values of chloride 10-15 mg/l phosphate 0.02 to 0.11 mg/l and nitrate 0.08 - 0.12 mg/l, moderate temperature, dissolved oxygen 8- 10 mg/l, low concentration of calcium hardness 20-36 mg/l, total alkalinity 94-122 mg/l, and nitrite very low, phosphate 0.02- 0.11 mg/l. Similarly during monsoon season Lower Lake was characterised by higher values of nitrate 0.04 - 0.15 mg/l ,oderate temperatu moderate concentration of dissolved oxygen 7.18 mg/l, chloride 28 - 39 mg/l , total alkalinity 115-142 mg/l, calcium hardness 56-79 mg/l, nitrite 0.003 - 0.008 mg/l, low concentration of phosphate 0.02 - 0.05 mg/l, and low values of pH. In Lower Lake post-monsoon season was characterised by high concentration of nitrate 0.04-0.16 mg/l moderate to high amount of calcium hardness 66-80 mg/l, phosphate 0.03 - 0.13 mg/l, total alkalinity 112 -132 mg/l, nitrite 0.001 - 0.008 mg/l, dissolved oxygen 5.0 - 8 mg/l, chloride 28 mg/l, moderate temperature and low values of pH (Tables 1-9).

In the year 1979-80 Cyanophyta showed two peaks, highest peak was recorded during post-monsoon and second peak was in summer season in both the lakes. In Upper Lake during post-monsoon physico-chemical characters were high dissolved oxygen, temperature, pH, total alkalinity, chloride, calcium hardness and moderate amount of phosphate and nitrate and low nitrite. But during summer pH, total alkalinity, chloride, calcium hardness and temperature were high, dissolved oxygen was moderate, phosphate, nitrate and nitrite were low (Tables 1-9).

In Lower Lake in post-monsoon Physico-chemical characters were, high nitrate, moderate to high chloride and phosphate, moderate values of total alkalinity, calcium hardness, nitrite, dissolved oxygen, moderate temperature and low pH. In summer season except phosphate and nitrate all the above mentioned parameters were high.

During 1930-81 in Upper Lake highest Cyanophycean peaks were observed in monsoon and post-monsoon and second peak was recorded in summer season. But in Lower Lake highest peak was observed in monsoon and second peak was during summer.

In Upper Lake monsoon season was characterised by high chloride content and phosphate, moderate temperature and dissolved oxygen, total alkalinity, pH and calcium hardness and low value of nitrite. Similarly, in Lower Lake in monsoon, chloride and nitrate were higher, dissolved oxygen and total alkalinity were moderate to high, pH, temperature and calcium hardness were moderate and phosphate and nitrite were low (Tables 1-9).

From the forgoing discussions it is amply clear that the algae exhibit considerable changes in response to the fluctuations in the physico-chemical properties of the aquatic environment. A number of workers have tried to classify lakes biologically and have considered the presence of certain algae to measure the water quality, and have identified a number of forms as indicators of pollution. The dominance of any algal type in a lake may indicate certain conditions and are therefore, worthy of discussion, for the trophic level of a body can also be described by presence of certain algal indicators.

The physico-chemical characteristics of the water varied from lake to lake. Atleast, some of the water parameters showed considerable variations from season to season while others showed much fluctuations and did not show a definite pattern. Although, the difference in the temperature and pH of the two lakes was marginal, the Lower Lake did show higher values of dissolved oxygen, total alkalinity, calcium hardness, chloride, nitrate, nitrite and phosphate. But these, in general, did not exhibit marked variations according to seasons. This lake with higher amounts of nutrients accounted for less number of algal taxa with higher number of individuals as against the other water body where the values of these factors were considerably less, but showed a large number of taxa. Analysis of the water of these lakes indicate that dissolved oxygen content in Lower Lake showed a wide range and it was more during monsoon and winter months. pH values point out that these lakes are alkaline. Generally, it was seen that pH was more in summer months when members of Euglenophyta were maximum and Cyanophyta showed the second highest peak. On the basis of the values obtained for total alkalinity Upper Lake is considered as moderate to high alkaline lake while the other is considered as highly alkaline water body. It showed comparactively higher values during summer season in both the lakes. Calcium hardness also showed an increase in this season in the former but such variations were not obvious in the other lake. Both are hard water lakes, but the Upper Lake has only moderately hard water. The higher chloride content in the Lower Lake is an index of pollution of animal origin. It showed an increase in summer and decrease in winter. There was an increase in nitrate content in both the lakes during winter and monsoon seasons but nitrite was found to be absent in many months in Upper Lake. The higher amount of nitrite in Lower Lake is considered as an indication that it is sewage polluted. The latter is rich in phosphate content too, with more of it during winter and monsoon seasons.

In Upper Lake maximum number of taxa of Chlorophyta was present in January in winter season when the physico-chemical characteristics of the water were a low winter temperature, moderate dissolved oxygen content, 8 -10 mg/1, pH -8.2 , total alkalinity 76 to 114 mg/1, chloride content 9 to 12 mg/1, moderate calcium hardness 14 to 37 mg/1, phosphate 0.09 to 0.11 mg/1 and high values of nitrate 0.09 to 0.11 mg/1. Nitrite was altogether absent (Tables 1-9). It is interesting to note that majority of the members were Desmids and Chlorococcales and the most frequent and dominant genera were *Cosmarium*, *Scenedesmus*, *Closterium*, *Staurastrum*, *Tetraedron* and *Pleurotaenium*. This group in Lower Lake showed peaks in different seasons. During the first year, the highest peak was in January. In the second year, however, it was in July, in monsoon season. It has been found that the magnitude of Chlorophycean peaks in this lake was comparatively low. This can be due to the presence of higher amount of nutrients and chemically rich nature of the lake.

The group Euglenophyta was represented in both the lakes by only 11 taxas. Largest number of taxa of Euglenophyta in Upper Lake was present in monsoon when the lake water contained higher amount of chloride 10 -15mg/1. phosphate 0.5 -0.11 mg/1, and nitrate 0.08 -0.11 mg/1, moderate values of dissolved oxygen 8 -10 mg/1, temperature, calcium hardness 14 - 38 mg/1, alkalinity 94 -122 mg/1., low pH and very low nitrite. But in Lower Lake peaks were in summer when there were high temperature, slightly higher concentration of dissolved oxygen 7 - 14 mg/1, total alkalinity 124 -149 mg/1, chloride 28 -39 mg/1, pH 8 - 8.4, calcium hardness 62 - 77 mg/1, nitrite 0.03 - 0.13 mg/1 and low concentrations of phosphate and nitrate. A look at the factors of both the seasons in both the lakes indicate that the members of this group occur comparatively in large numbers under conditions of high water temperature and more dissolved oxygen and chloride content (Tables 1-9). The dominant genera in the two lakes were Trachelomonas, Phacus, Euglena and Lepocinclis.

When compared to Euglenophyta, the members of Chrysophyta were more. In Upper Lake maximum number of species was recorded in monsoon season while in Lower Lake peaks were recorded in monsoon and post-monsoon seasons. Maximum number of species was present in the first lake. In monsoon the second lake showed 0.04 - 0.15 mg/1 of nitrate, moderate temperature, dissolved oxygen 7-18 mg/1, chloride 28 -39 mg/1, total alkalinity 135 -142 mg/1, calcium hardness 56 -79 mg/1, nitrite 0.003 - 0.05 mg/1 and comparatively low phosphate and pH. In post-monsoon, chloride and phosphate were little more and dissolved oxygen was comparatively less.(Tables 1-9). The dominant forms in these lakes were Navicula, Gomphonema, Nitzschia, Cymbella and Melosira.

The highest Cyanophycean peaks in Upper Lake in the first year was in November, in post-monsoon followed by a second peak in April, in summer. During post-monsoon the physico-chemical characters of the water were high dissolved oxygen and temperature, pH, total alkalinity, chloride, calcium hardness and temperature were high, dissolved oxygen were moderate and phosphate, nitrate and nitrite were low. In the second year the highest Cyanophycean peaks were observed in monsoon and post-monsoon seasons. Thus, it can be seen that the members of Cyanophyceae occurred in their maximum in these lakes when there was moderate to high dissolved oxygen content, temperature, pH, total alkalinity, calcium hardness, low to moderate phosphate content and low nitrate and nitrite (Tables 1-9). Species of Oscillatoria, Microcystis, Anabaena and Merismopedia were well represented.

In the first year members of Cyanophyta in Lower Lake showed the highest peaks in post-monsoon and summer seasons. In post-monsoon, the physico-chemical characters were high nitrate, moderate to high chloride and phosphate, moderate values of total alkalinity, calcium hardness, nitrite, dissolved oxygen, moderate temperature and comparatively low pH. In summer seasons except phosphate and nitrate all the above mentioned parameters showed high values.

In the second year the higher peaks were observed in monsoon and summer seasons. In monsoon, chloride and nitrate were higher, dissolved oxygen and total alkalinity were moderate to high, pH, temperature and calcium hardness were moderate and phosphate and nitrite were low. *Microcystis*, *Lyngbya* and *Merismopedia* were the dominant forms.

It has been shown that these lakes are polluted but the degree of pollution varies. Upper Lake is characterised by the presence of indicators of pollution like the increase in chloride, depletion in dissolved oxygen and increase in nitrate and phosphate. But the values for these indicators are very high in Lower Lake and therefore, it is a highly polluted one. These factors also indicate that the two lakes are eutrophic and the Upper Lake is slightly eutrophic and Lower Lake is highly eutrophic.

An effort has been made to identify algae as possible pollution indicators and to determine the trophic levels. It is pertinent to note that Nygaard's Compound Quotient also points to the eutrophic nature of the lakes. Its value is very high for the Lower Lake. Sixty one taxa of algae characteristic of highly eutrophic lake and 218 taxa characteristic of slightly eutrophic lake have been identified.

According to Garett (1963) in the ultimate analysis, it was the physico-chemical characteristics of a habitat that determines the kind of community that will occupy it.

Hence in the present study impact of some physico-chemical factors, such as temperature, pH, total alkalinity, dissolved oxygen, calcium hardness, chloride, nitrite, nitrate and phosphate content of water, on the growth and occurrence of the aquatic fungi in two lakes of Bhopal have been studied in detail. During the course of present investigation a total number of 42 fungal forms belonging to Chytridiales, Blastocladiales, Saprolegniales, Lagenidiales and Peronosporales have been isolated. In the preceeding pages the factors in relation to these aquatic fungi and their seasonal occurrence are being discussed in detail.

Temperature of Water

There are a number of factors operating at a site, out of them temperature seems to be of great importance. It acts directly upon such processes as germination of overwintering structures for vegetative growth, and for induction of sexual reproduction by means of zoospores. Various researchers like Paterson (1960), Perrott (1960), Dayal and Tandon (1962, 1963), Roberts (1963), Schmitt (1967), Srivastava (1967), Alabi (1971 a,b), Khulbe and Bhargava (1977), Hasija and Batra (1978) and Rattan etal (1980) also found that temperature plays an important role in the occurrence of aquatic fungi.

In the present investigation it was found that the fluctuation in fungal occurrence was dependent upon water temperature. There was not much difference in the variation of the mean monthly water temperature of both the lakes. It is also obvious that, as the temperature rises, the occurrence of fungi declines. In both the lakes maximum number of fungal forms were obtained during winter and monsoon seasons, while the minimum fungal forms were recorded during summer. Thus it is evident that high summer temperatures have an inhibitory effect on the occurrence of fungi, while the low and moderate temperatures of winter and monsoon seasons favour the fungal occurrence. The maximum zoospore production and induction of sexual organs were observed at a temperature range varying from 16 -29.5°C. The studies of Saksena and Rajgopalan (1958) also revealed similar type of results. They have reported twelve aquatic fungi from Sagar, of which eight species appeared during the months of December and January. The present findings agree with those of Forbes (1935 b), Waterhouse (1942), Dayal and Tandom (1962, 1963), Huges (1962), Roberts (1963), Srivastava (1967), Khulbe and Bhargava (1977), Manoharachary (1978, 1979 a,d), Manoharachary and Ramarao (1981 a,b) and Rattan etal (1980). Suzuki (1960 a,b and d) observed that temperature has a profound effect upon zoospore production due to unfavourable temperature conditions were obvious. Suzuki and Hatakeyama (1961) further emphasized that zoospores of aquatic fungi showed considerable variation in amounts, with the maximum in autumn and the minimum in summer and late autumn. Barksdale (1960) reported that the induction of sexual organs, both on single thallus and on paired thalli is temperature dependent. Sexual organs were initiated at 15-20°C in many strains of Achlya. Milanez and Doval (1969) and Krause (1960) suggested a wider temperature range of 20-30°C for oogonial formation. Srivastava(1967) considered 18°c as the most suitable temperature for the growth of most of the aquatic fungi. Khulbe and Bhargava (1977) found that maximum frequency of water molds recorded between 18-22°C which they considered as moderate temperatures. Schmitt (1967) mentioned that as the temperature increased, there was a corresponding decrease in the diversity of fungal species isolated from lake taxoma. Hasija and Batra (1972) found that Achlya americana was prevalent in water with temperature

22-28°C and high temperatures (33 -41°C) did not favour its occurrence. Rattan et al(1980) also found that a low temperature of 11°C in January at Shatt-Al-Arab was most favourable for water molds while high temperature of 32°C in July proved to be inhibiting. Recently Khan (1981) regarded 27-30°C temperature as most suitable one for fungal occurrence.

Results of the present study also showed that occurrence of fungi was inversely correlated with temperature. During the course of present investigation, temperature ranged from 16 to 32.5°C. Maximum fungal species i.e. out of 35, 12 and 15 in Upper Lake and out of 26, 11 and 14 in Lower Lake, occurred within the temperature range of 16 to 29.5°C in 1979-80 and 1980-81 respectively. Similarly the minimum fungal occurrence i.e. out of 35 forms 3 and 4 in Upper Lake and out of 26 only 4 in Lower Lake was recorded in the temperature range of 29.5 - 32.5°C. Although in the present study March was included in summer months , it showed a temperature between 27.6 - 29.6°C which was found to be favourable for the occurrence of some of the fungi. Similarly June was considered as a monsoon month but during both the years of study high temperature prevailed during this month as well, that is why very few fungal forms were recorded during this period.

Results of the present investigation fully agree with the earlier researches, as most of the members of Saprolegniales were recorded during low to moderate temperature range of 16 -29.5°C, while some members of Peronosporales can equally flourish well ever in high summer temperature of 29.6 to 32.5°C. Members of Saprolegniales like Saprolegnia diclina, S. ferax, *Aphanomyces laevis* and *Aphanomyces* sp. were also reported during high summer temperature. It has been further supported by the observations of Khulbe and Bhargava (1977) and Khan (1981) who considered Saprolegnia ferax and S. diclina as constant or high temperature species. However, Srivastava (1967) considered these species as low temperature species but *Aphanomyces laevis* was unanimously considered as constant species, which appeared in all seasons during present study also.

Considering the temperature requirement for each fungal species, Roberts (1963) classified aquatic fungi in three groups namely: (i) Winter species, (ii) Summer species and (iii) constant species which occurred in all seasons. Similarly, Srivastava (1967) classified aquatic fungi of Gorakhpur in low temperature species and constant species. Khulbe and Bhargava (1977) used a wider classification and they have divided aquatic fungi, reported from Nainital region, into four groups according to their preference of temperature range:

(i) Constant species : with a temperature range from 10 to 28.5°C.

(ii) Low temperature species: with temperature range from 10 to 18°C.

(iii) Moderate temperature species: with temperature range from 15 to 23.5°C.

(iv) High temperature species: with temperature range 16 to 28.5°C.

Manoharachary and Ramarao (1981 a) also divided aquatic fungi in -

Monsoon species (June- September), Winter species

(October -January), Summer species (February to May) and constant species (all seasons).

In the present study too, it was observed that for a particular species, a distinct temperature requirement was noted. This preference for temperature greatly vary from species to species. It was difficult to place the species collected from Bhopal in the four categories proposed by Khulbe and Bhargava (1977) as there exists a considerable difference in the water temperatures of water bodies of Nainital and that of the two lakes of Bhopal. A low winter temperature of 10 -18°C has been reported from Nainital but it varied from 16-25°C in the two lakes under study. Likewise the summer temperatures also vary. Considering the differences in temperature, the present fungal forms have been grouped under four separate categories. Fungal forms corresponding to their temperature classes are presented below:

I. *Low temperature species:*

Fungal forms which prefer a temperature range from 16 to 25°C have been put under this group. Only nine species belonged to this category:

Rhizophydium carpophilum, *Diplophlyctis intestina*, *Rhizidium* sp., *Blastocladiella novaezeylandiae*, *Leptolegnia* sp., *Achlya flagellata*, *Dictyuchus monosporus*, *D. pseudoachlyoides*, *D. sterile*.

II. *Low to moderate temperature species:*

A temperature range from 16 to 29.5°C was found to be favourable for the following 19 fungal forms:

Olpidium utriculiforme, *Blyttiomyces spinulosus*, *Entophlyctis bulligera*, *Chytridium olla*, *Catenophlyctis variabilis*, *Blastocladia sparrowii*, *Protoachlya paradoxa*, Achlya apiculata, A. conspicua, A. hypogyna, A. imperfecta, A. klebsiana, A. megasperma, A. oblongata, A. oligacantha, A. orion, A. prolifera, A. proliferoides and Lagenidium pygmaeum. These forms were predominatly available in winter and monsoon but they also survived in Postmonsoon and in early summer.

III. Moderate to high temperature species:

Five species recorded in the temperature range of 25- 32.5°C come under this category. These were:

Saprolegnia furcata, Myzocytium proliferum, Pythium aphanidermatum, Pythium and Phytophthora gonapodyides. Though these were available in monsoon and post-monsoon, they equally well represented in summer.

IV, Constant species:

Nine species occurred in all seasons and flourished under a wide range of temperature fluctuations from 16 to 32.5°C, were kept under this group:

Karlingia aurantiaca, Saprolegnia diclina, S. ferax, Achlya sp., Aphanomyces laevis, Aphanomyces sp., Pythium middletonii, P. debaryanum and Pythiogeton ramosum were considered as constant species.

Thus from the perusal of the above classification, it is obvious that the majority of fungi are in low to moderate group with a temperature range from 16 to 29.5°C. Most of the species of Achlya, which was found to be the dominant genus also preferred the same temperature range.

Suzuki (1960) considered Achlya flagellata and Dictyuchus sp. as low temperature species. Roberts (1963) found Achlya megasperma and A. oblongata as winter species. Srivastava (1967 b) recorded Achlya orion, A. flagellata, A. proliferoides, A. prolifera, A. conspicua, A. klebsiana, *Dictyuchus sterile* and *Leptolegnia* sp. as low temperature species. Khulbe and Bhargava (1977) also considered *Achlya flagellata* and *Protoachlya* sp. as moderate temperature species. Manoharachary and Ramarao (1981 a) regarded *Achlya proliferoides* as monsoon and *A. orion* as winter species. During the present study all these fungal forms have been recovered within low or low to moderate temperature range.

Roberts (1963) and Srivastava (1967) considered *Saprolegnia diclina* and *S. ferax* as low temperature species but in the present study both these forms were regarded as constant species. This observation was in full agreement with the findings of Suzuki (1960 d), Khulbe and Bhargava (1977) and Khan (1981). However, Manoharachary and Ramarao (1981 a) and Khan (1981) reported *Achlya klebsiana* as constant species but it was found to be a low to moderate temperature species as was described to be low temperature species by Srivastava (1967). *Aphanomyces laevis* was described as a winter species by Roberts (1963 a) but it was found here to be a constant species.

It was also noted that Chytridiales and Blastocladiales prefer either low or low to moderate temperature range, with the exception of *Karlingia aurantiaca* which occurred as a constant species. In the present study *Rhizophydium carpophilum* was found to occur in temperature ranging from 20-21°C. But species of genus *Rhizophydium* was reported to occur in a wide temperature range of 20 -30°C by Barr (1969).

Most of the members of Peronosporales were found either in moderate to high temperature or constant species group. Srivastava (1967) regarded *Phytophthora gonapodyides* as low temperature species but it was reported under moderate to high temperature group during the present study. Similarly, species of pythium also occurred in the same group. These observations agree with those of Haskins (1963) who found a temperature range of 10 -33°C for the occurrent of Pythium with an optimum between 30 -31°C. Suzuki (1960 a) also found Pythium occurring thoughout the year. Schmitt (1967) pointed out Pythium as 'harder' in the temperature tolerance than the genera of Saprolengniales.

From the above discussion, it is obvious that temperature is one of the most important factors in determining the occurrence of aquatic fungi. It was found that low to moderate temperature favours the occurrence of aquatic fungi, while high temperature appears to be inhibiting.

Hydrogen ion concentration (pH) of water :

The effect of pH of water on the occurrence of fungi has also been considered as an important factor by various workers. Lund (1934) has classified fungi in five groups i.e. (I) Highly acid (pH 3.5 - 4.0), (II) slightly acid (pH 5.3 - 6.8), (III) neutrally acid (pH 6.2-7.5), (IV) neutrally alkaline (pH 6.5 -7.7) and (V) constantly alkaline (pH 7.6 -8.4). He found out that water with moderately acid, neutral or alkaline, pH values have no specifically defined Saprolegniaceous flora, but some species thrive vegetatively on both acid and alkaline substances, whereas, the formation of reproductive organs seem to be conditioned by a specific range of pH.

Following the trend of Lund (1934), Roberts (1963) classified the distribution of twenty six species in relation to pH, under three categories viz.,

(I) acid group (pH below 5.2), (II) alkaline group (pH above 7.8), (III) neutral group (pH between 5.2 and 7.4). Srivastava (1967) also placed thirty species of water molds recorded from Gorakhpur under three pH groups i.e. (i) Acid group (pH 5.6 -7), (II) alkaline group (pH 7- 8.8) and (iii) neutral group (pH 5.6 - 8.8).

Willoughby (1962 a, 1964) pointed out that some species were confined to only low pH. Dick (1963) that moderately inferred acidic soils have a considerably greater number of species of saprolegniaceous fungi than was found in highly acidic or slightly acid to a alkaline soils. There was a group of species characterised by quite a vide range of tolerance for pH which included some species of Achlya, Isoachlya and Pythiopsis.

However, during the present investigation, such demarcations of fungi according to their pH requirements could not be ascertained. Because throughout the course of investigation, the pH value of water in both the lakes ranged between 7.4 - 8.7, which fell under neutrally alkaline and constantly alkaline groups of Lund (1934), alkaline group of Roberts (1963) and Srivastava (1967). Thus basically the water of both the lakes showed an alkaline pH, although there existed minor seasonal variations in the pH of water that too, in alkaline side.

The pH of water in both the lakes followed a general trend with maximum pH value during summer season, while during winter and monsoon seasons it was comparatively low. Results of the present investigations showed that pH of water was sometimes higher during winter months in Upper Lake. This increased pH may be a resultant of various biological activities operating at that time. Juday et al

(1935) found out that pH and lakalinity are brought about primarily through biological processes. Paterson (1960) considered that photosynthetic activity of autotrophs is responsible for the removal of CO_2 which would be expected to increase pH. This may be one of the reasons for high pH value during winter season. In summer seasons also algal blooms were very common at the collection sites which may be, responsible for high summer pH along with some other factors. Although, there was no definite pattern of the seasonal fluctuations in pH values in both the water bodies, even then maximum fungi were recorded between a pH range from 7.4 to 8.2. Very few fungal forms were recorded above this range.

Suzuki and Katakeyama (1960) found that one species of Pythium was distributed only in the lakes of neutral water and was never found in acid waters, while Saprolegnia diclina, Aplanes braunii and Leptolegnia caudata were found in the acid waters. Suzuki (1961 f,d) reported Saprolegnia monoica var. acidamica from acidotrophic lakes of Japan and indicated that the fungi were very scarce or absent in the lakes with lowest pH. He has recorded maximum number of fungi in the pH value of 5.8. Krause (1960) found that oogonia of Saprolegnia ferax formed only in a pH range of 5.2 - 7.2.

In the present study, Saprolegnia diclina, S. ferax, Leptolegnia sp. Pythium sp., and species of Aphanomyces were recovered from neutral to alkaline or constantly alkaline waters which are characteristic of both the lakes. Srivastava (1967) recorded Phytophthora gonapodyides in a pH range of 5.6 to 7, but during present study it occurred in a pH range of 7.9 to 8.4. Moreover, he has reported

Achlya prolifera, *A. conspicua*, *Dictyuchus monosporus* and *Leptolegnia* sp. in the pH range of 5.6 to 8.3, which is in close confirmity with the present findings. Suzuki and Hatakeyama (1960) regarded Leptolegnia caudata as an acidic species but the observations of Srivastava (1967 b) as well as present findings confirm the occurrence of *Leptolegnia* sp. in alkaline waters too.

Highly acidic water is considered to be injurious to aquatic fungi, while moderately acidic to alkaline water appeared to be favourable for these fungi. Okane (1981) found a very small amount of zoosperes in acidic waters than those showing pH above. Rai and Misra (1977) reported Saprolegniaceous fungi from alkaline soils and ponds with a pH range of 7.5 to 8.8 from Lucknow. They have recorded *Achlya hypogyna* and *Achlya oblongata* at pH 8.5 and 8.8 respectively. Hasija and Batra (1978) observed that a pH range of 7.1 to 7.9 favoured the growth of *Achlya americana*. Manoharachary (1979a), Manoharachary and Ramarao (1981b) found that most of the aquatic fungi have the tolerance for a wide range of pH. They have found that pH range between 7.6 and 8.2 to most favourable to microbial.

The findings of the present investigations are in conformity with the results of the above mentioned researches in that the saprolegniaceous fungi prefer an alkaline pH. The observations of Alabi (1971 b) from tropical waters of Nigeria also tally with the results of the present study. He pointed out that more species of saprolegniaceae occurred when the pH was above 7 and less when it fell below 7.

Thus it can be concluded that fungi recorded from the lakes of Bhopal belong to neutrally alkaline pH group, and such a type of water favours a good growth of fungi belonging [illegible] to various groups of Phycomycetes.

However, Cochrane (1958) considered that pH is not the unitary factor, incluencing the growth of fungi. Lund (1934), Dayal and Tandon (1962, 1963), Srivastava (1967b) and Liu and Volz (1976) also emphasized that pH alone can not be considered as decisive factor as they have described a number of species of aquatic fungi from all the pH groups. Thus, pH along with some other factors, influence the occurrence of fungi.

Total alkalinity of water:

Water is described as alkaline when the hydroxylion concentration exceeds to any degree, the hydrogen-ion concentration. The average alkalinity of Upper Lake fluctuated between 76 mg/l to 124 mg/l, while the Lower Lake showed an average alkalinity range from 112 mg/l to 149.2mg/l. Lower Lake has always been found to be more alkaline than Upper Lake.

Philipose (1960) classified Indian confined waters in three categories on the basis of total alkalinity:

I. Waters with low alkalinity (4-50 ppm)
II. Waters with moderately high alkalinity(50-100 ppm.)
III. Waters with high alkalinity (100-200 ppm.)

On the basis of data available, it is seen that Upper Lake occupies a position in between the categories two and three of moderately high to high alkaline waters, while Lower Lake strictly falls under category three i.e. high alkaline waters.

It has been found that in general, total alkalinity showed a direct relation with temperature of water. It was found to be inversely related with fungal occurrence in both the lakes. Even though the total alkalinity of

Lower Lake was higher than Upper Lake, it also followed almost the same trend of fungal occurrence. In both the lakes total alkalinity was comparatively higher in summer than the other seasons, when minimum fungal occurrence was recorded. Most of the members of Chytridiales, Blastocladiales and saprolegniales were found to be unable to tolerate the high alkaline conditions. However, members of Peronosporales such as *Pythium aphanidermatum*, *Pythium debaryanum*, *Pythium middletonii* and a few saprolegniaceous and chytridiaceous fungi like *Saprolegnia diclina*, *saprolegnia ferax*, *Aphanomyces laevis* and *Karlingia aurantiaca* were very well capable to survive in high alkaline water. Except these, the occurrence of fungi during present investigation was inversely related with the total alkalinity of water.

Dissolved oxygen of water :

According to Sparrow (1968) oxygen appeared to be a major factor in determining the occurrence of fungi in water. Liu and Volz (1976) described that members of the Saprolegniaceae typically require an abundance of oxygen. They believed oxygen to be one of the limiting factors for the growth and occurrence of these organisms.

The dissolved oxygen in water of Upper Lake ranged from 7.0 to 10.6 mg/l during both the years. It was more during monsoon and winter months as compared to summer season. In Lower Lake a wide range of variation in the dissolved oxygen content was recorded. It varied from as low as 4.2 mg/l to as high as 18.5 mg/l. Therefore, it is evident that there existed a significant difference in the dissolved oxygen content of water of both the lakes. Moreover, its content in Lower Lake did not follow any particular trend, which may be due to enormous addition of pollutants like sewage from the thickly populated surrounding area. Ganapati (1943) inferred that oxygen content of lakes are normally affected by several factors, viz., water movement, pollution from animals, addition of springs or under ground water, production of oxygen by plants and its consumption by plants, animals and bacteria. Thus the amount of oxygen present at any time in the lake will be the combined result of several factors. The collective impact of various factors govern the irregularity in the oxygen regime.

Dissolved oxygen in the Upper Lake showed an inverse correlation with temperature with maxima in monsoon and winter and minima in summer season. The existance of such a relationship has already been established by a number of earlier researchers through out the world. But in the case of Lower Lake no such relationships were observed. One of the reasons behind the irregularity of dissolved oxygen content of water of Lower Lake might be the influence of luxurient growth of Eichhornia crassipes. A continuous mat of this plant existed throughout the course of study. During winter season it had occupied most of the surface of water and used to float from one place to the another. Rai and Dattamunshi (1979) also observed a lower level of oxygen content under the water hyacinth areas than in the open water. In Lower Lake minimum value of 4.2 mg/1 dissolved oxygen was recorded in January 1980, when the surface of the water was thickly covered by water hyacinth as compared to other months.

In Upper Lake monsoon and winter seasons showed high dissolved oxygen as well as rich fungal flora. Maximum fungi occurred in the winter having higher values of dissolved oxygen ranging from 8.2 - 10.5 mg/1. Minimum fungal forms were recorded in the summer when the dissolved oxygen content of water was also low. This observation agrees with the findings of Suzuki (1961 b) who correlated diurnal migration of zoospores of aquatic fungi with the dissolved oxygen and found a direct correlation between dissolved oxygen content of water and zoospore migration. Dayal and Tandon (1963) considered dissolved oxygen as a significant factor in fungal occurrence.

In the Lower Lake the fungal occurrence did not follow any particular pattern with regard to the level of dissolved oxygen. In August 1979, dissolved oxygen was highest but only seven fungal species were isolated. On the contrary, fifteen fungi were recorded in the month of January 1980 when dissolved oxygen was low. The same trend was found in August, September 1980 and January 1981. This correlation between the dissolved oxygen and the occurrence of fungi could not be established in Lower Lake. Lund (1934) pointed out that there were certain forms which typically required an abundance of oxygen e.g. members of Saprolegniaceae and Leptomitaceae while others such as Rhipidium Gonapodya, Blastocladia, Pythiogeton etc. may even grow under conditions of low oxygen content. For Blastocladia and Pythiogeton Emerson and Cantino (1948) and Cantino (1940 a,b) found that such fungi were capable of fermentative metabolism. However, in the present study Blastocladia sperrowii was reported only from one sampling site of Upper Lake where dissolved oxygen was always found to be in the normal range. This fungus was never isolated from the Lower Lake. In fact, during the present study whatever amount of dissolved oxygen was recorded from both the lakes, fell in normal to high saturation categories.

The so called hazardous or oxygen deficient situation was never obtained. Irrespective of some forms which are confined either to Upper Lake or Lower Lake, both the lakes support the growth of Saprolegniaceaus fungi well, because the dissolved oxygen was available in enough quanity. Manoharachary (1979a) observed that the dissolved oxygen 4.7 to 12.3 ppm was favourable for the Phycomycetous fungi. Rattan et al (1980) considered water with 5.8 -9 ppm dissolved oxygen as saturated one. The results of the present study indicate that water having 4.2 to 18 mg/l of dissolved oxygen is favourable for the growth of aquatic phycomycetes. Although there was a very high dissolved oxygen level in the Lower Lake during May 1979 the number of species was very low.

Alabi (1971 b) and Manoharachary (1978) found that oxygen content was insignificantly correlated with the occurrence of aquatic fungi. Rattan et al (1980) opined that the amount of dissolved oxygen is dependent on the temperature and it does not play any direct role in the seasonal occurrence of aquatic fungi, on the basis of the results of the present study it is obvious that there exists a direct relationship between the occurrence of aquatic fungi and the amount of dissolved oxygen in Upper Lake while no such relations could be established in the Lower Lake.

The calcium hardness of water of Upper Lake varied from 14.5 mg/l.to 41.5 mg/l. With maximum values in the month of May and June and minimum in November and December. Lower Lake showed a variation in calcium hardness from 56.5 to 84.5 mg/l with maximum in the month of June and October and minimum in the month of August and May.

Lower Lake was found to be richer in calcium hardness than Upper Lake. It is obvious that the water of Lower Lake was harder than Upper Lake. The maxima and minima peaks were also found to be different for both the lakes.

In Upper Lake fungal occurrence sometimes showed an indirect relation with hardness. Because when the calcium hardness in November, December, 1979 and October 1980 to January, 1981 was low, a high fungal occurrence was recorded. On the contrary, calcium hardness values were high during February to September 1980 except for August and March to June 1981, which showed a marked decline in the occurrence of fungi. But in August 1980 the number of fungal forms as well as calcium hardness were high. Lower lake also showed a significant variation in fungal occurrence irrespective of very high calcium hardness. Thus it seems that calcium hardness had no direct impact on fungal occurrence.

Basu (1952), Ingraham and Emerson (1954), Lopatecki and Newton (1956), Erwin and Katznelson (1961) that calcium stimulated growth of *Allomyces* and *Phytophthora* sp. Willoughby (1962 c) studied the role of calcium on fruiting behaviour and nutrition of *Cladochytrium replicatum* and found that calcium was necessary to give maximum yield and that low concentration was inhibitory. Davis (1959) Erwin (1968) and Hendrix and Guttman (1970) showed that *Phytophthora parasitica* var. *nicotianae* had an absolute requirement for calcium. During the present investigation *Phytophthora gonapodyides* was reported in the month of October 1979, March 1980 and March, April, 1981 from Upper Lake and during March, April of both the years from Lower Lake when it showed low calcium hardness values of 25-35 mg/1 and high 66-67 mg/1 in Upper and Lower Lake respectively.

It may be concluded that P. gonapotyides occurs in water having good amount of calcium ranging from 25 mg/1. It is also true that calcium hardness alone can not be considered as limiting factor for the occurrence of other aquatic fungi, as was mentioned by Cochrane (1958). According to him the effect of calcium may be non-nutritional and associated with protection against the injurious effects of certain monovalent cations and in general, fungi do not require calcium. Dayal and Tandon (1963) and Khulbe (1981 a) also found hardness as quite insignificant factor in the occurrence of most of the aquatic fungi. The above observations are in agreement with the findings of the present investigation, though calcium may play an indirect role in the growth and occurrence of aquatic fungi by influencing other physico-chemical characters of water.

Chloride content of water:

In both the lakes maximum chloride content values were obtained during summer months as well as in first two months of monsoon, i.e. June and July when there was a comparatively high water temperatures. A low chloride content was recorded during winter season. Similar results were also obtained by Dayal and Tandon (1963) and Zafar (1964).

Lower Lake showed an exceptionally higher concentration of chloride than Upper Lake. It has been observed that Lower Lake received a large amount of sewage from the surrounding localities. This appears to be one of the reasons for the high chloride content of this lake. Thresh et al (1944) also opined that the higher chloride content of water is an index of pollution of animal origin.

The species diversity in Lower Lake was lesser than Upper Lake and the occurrence of fungi was more in the period of low chloride content of water. Thus chloride appears to be inhibitory for the fungal occurrence. Pagon (1970) considered that chloride may be fungitoxic for the members like candida albicans which are human pathogenic organisms. Jeanette and Schmitt (1978) also studied the effect of chlorination on the survival of cells of candida albicans and confirmed the ability of chloride to disinfect waste water. Khulbe (1981 a) also found that chloride had an adverse effect on the fungal occurrence. This is in close conformity with the present findings.

Nitrite

The nitrite content of water of Upper Lake fluctuated between 0 and 0.008 mg/1. The maximum values were recorded during May and August, 1980. It was nil during July, November, December, 1979, January, July and December 1980 and January, 1981.

In Lower Lake nitrite was present in all the seasons. It varied from 0.001 mg/1 to 0.015 mg/1. Maximum nitrite content was recorded in the month ofFebruary 1980 and March, April, 1981, while the minimum was reported during November, December 1979 as well as in May, June and October, 1980.

Manoharachary (1978, 1979 d) also reported maximum nitrite values in February and November and minimum in September and March respectively in two different water bodies of Hyderabad. Dayal and Tandon (1963) reported nitrite almost absent from all the three water bodies under study at Allahabad. Manoharachary (1978, 1979 d), Manoharachary and Ramarao (1981 b) considered nitrite as an insignificant factor for the fungal occurrence. The results of the present findings in general agree with the opinion of Manoharachary (1978 - 1979) and Manoharachary and Ramarao (1981).

Nitrate content of water:

Inorganic nitrogen forms an important source for aquatic Phycomycetes. Dayal and Tandon (1963) and Manoharachary (1978, 1979 d), Manoharachary and Ramarao (1981 b) showed that nitrate favoured the distribution and qualitative composition of aquatic Phycomycetous fungi.

In the present investigation, nitrate content of water varied from 0.03 mg/l to 0.17 mg/l in the Upper Lake. The maximum values were recorded during February, August 1980 and January 1981. Minimum nitrate content was recorded during the month of May 1980, and March 1981. Similarly, in Lower Lake the range of nitrate content was 0.01 mg/l to 0.19 mg/l. Maxima was recorded during August 1979, January March and September, 1980. Lowest nitrate values for Lower Lake were recorded during November 1979 and June 1981.

It has been found that as the nitrate content of water increased the occurrence of fungal species also enhanced in the Upper Lake. Lower Lake did not show any definite relationship between the fungal occurrence and nitrate values of water during both the years of investigation.

Leonian and Lilly (1938), Bhargava (1945 a), Whiffen (1945), Cantino and Turian (1959) and Powel et al (1972) have reported the unability of Saprolegniaceae to absorb nitrate nitrogen. The above findings agree with the observations recorded for Lower Lake, because from July to November 1979 and September 1980 to February 1981 occurrence of Saprolegniales showed an inverse correlation. However, it is not true for Upper Lake. Due to these hostile findings of both the lakes, no definite correlation between fungal occurrence and nitrate content of water could be established.

Phosphate content of water :

Phosphate content of water has been considered as an important factor for the fungal occurrence by Manoharachary (1978 and 1979 d).

The phosphate content of water of Upper Lake fluctuated between 0 to 0.11 mg/l. The maximum phosphate values were recorded during January and July, 1980, while the minimum was obtained during May and June of both the years. In Lower Lake it ranged from 0.01 to 0.14 mg/l with highest values in the month of December 1979 and November 1980, while the lowest values were recorded during July 1979, June and August 1980.

Lower Lake was found to be richer in phosphate content than Upper Lake which might be due to the high pollutant lead in the form of sewage. Welch (1952), Ruttner (1953) and Hutchinson (1957) have also recorded high values of phosphate in waters contaminated with sewage or agricultural drains.

In both the lakes high phosphate content was recorded during colder months while summer months had a low phosphate content. Regarding such seasonal variations in phosphate content, Manoharachary (1979 d) viewed that the summer decline of phosphate can be attributed to the non-availability of specific bacteria and fungi that can decompose the type of organic matter present in these ecosystems.

Generally in both the lakes the fungal occurrence was maximum in winter months when the phosphate content of water was high. Fungal occurrence declined to a very low level in summer months alongwith the phosphate level. Though during this study some irregular findings of phosphate content were also recorded,the reason behind this was uncertain. However, the present findings in general agree with the observation of Manoharachary (1978 a) that a positive correlation between fungal, numbers and phosphates of water exists.

Pollutants and fungal occurrence:

Weston (1941) described that the aquatic Phycomycetes such as Monoblepharidales and certain Saprolegniaceae thrive best in clear, pure water. In the present investigation it was noted that both the lakes are polluted but Lower Lake is highly polluted. High concentration of chloride, phosphates, nitrites and nitrates, irregularity in the values of dissolved oxygen content, and enormous growth of aquatic weeds clearly indicate the state of high eutrophication and high degree of water pollution in Lower Lake. Upper Lake is also polluted because of the presence of chemical indicators of pollution like increased chloride, the depletion in dissolved oxygen the increase in nitrites and phosphates. Shastry et al (1970) also made same observations.

The total number of 26 fungal forms were isolated from Lower Lake while from Upper Lake 35 fungal forms were recorded. The species diversity was lower in the Lower Lake than that of the Upper Lake. Moreover, only 308 positive isolations were recorded from Lower Lake as against 362 from Upper Lake, which clearly indicates low occurrence of aquatic fungi in Lower Lake. Only seven species were strictly confined to Lower Lake viz., Saprolegnia furcata, Achlya flagellata, A. orion, A. prolifera, Dictyuchus

Pythium sp. These fungal
ving in highly polluted
confined to Upper Lake
Rhizophydium carporhilum
tis intestina, *Blastocladiella*
crowii, *Leptolegnia* sp.
lata, *A. imperfecta*, *A.*
cantha, *A. proliferoides*,
hanidermatum. It appears
ow in highly polluted waters.
grow equally well in both
waters.
Aphanomyces and *Allomyces*
er whereas *Geolegnia* has
th any degree of pollution.
ia, *Achlya*, *Dictyuchus*,
obtained with a mild degree
a and *Dictyucus* were mostly
rs. But *Aphanomyces* showed
.
olegnia was not reported .
olegnia furcata, *Achlya*
a species of *Dictyuchus*
ke. Although, *D. monozporus*
, but it was very rare.
orted from both the lakes, .
loving species by Harvey
that both the lakes have
ver Lake was comparatively
cording to the opinion of
and *Dictyuchus* grow in

non-polluted or least polluted waters. But the present findings do not support this view because these genera were isolated from highly polluted Lower Lake too.

Khulbe (1981 b) reported a number of aquatic fungal forms common to polluted and non-polluted lakes, although their frequencies were different, polluted water in his study showed high frequency of these fungi. Suzuki (1960 d) examined the distribution of zoospores of aquatic Phycomycetes in the Arakawa River in Japan and inferred that they were scarce in the upper reaches of the river and increased in its lower part, becoming most abundant in its middle course, and diminished with the increase of pollutants in its lower reaches. Rattan et al. (1980) also found that pollutants inhibit the fungal occurrence. They have reported maximum fungi from Quarna which was a clean water station. In the present investigation it has been found that the highly polluted Lower Lake showed less number of aquatic fungi than Upper Lake.

From the analysis of the physico-chemical parameters and the flora of both the lakes, it is also clear that the surrounding catchment areas are the major sources of nutrient enrichment for Upper Lake. The fertilizers added to the agricultural fields get entry into the lake through rain water. The dumping of sewage is an additional factor which hastens the process of eutrophication and water pollution. The increase in phosphate content of water is generally brought about through point sources like sewage, detergents and drainage and nitrogen content by agricultural run off, nitrogen fixation and precipition. Besides sewage, one of the phosphate source to natural waters of greatest concern is domestic waste water.

Periodicity of Fungi

Aquatic fungi follow a particular periodicity pattern for their occurrence which depends upon the prevailing physico-chemical conditions at a site. Coker (1923) inferred that great majority of Saprolegniaceous fungi occurred between winter and summer in North Carolina.

Chaudhuri *et al* (1947) reported that favourable growth period for Saprolegniaceous fungi are in October to mid December. Similarly Dayal and Tandon (1962) found that species collected during October and November showed vigorous growth and produced sex organs within a short duration of time. They opined that most species of Saprolegniales become dermant with the approach of high temperatures and germinate, following low temperatures. *Aphanomyces sp.* was the most commonly occurring species and was recoverable from August to April.

Srivastava (1967b) recorded first appearance of water molds between July and September which continued growing upto March. There was another group of low temperature plants which occurred from October to January. Most of the aquatic fungi showed a seasonal periodicity which declined in February or March and completely disappeared from April to June. Khulbe and Bhargava (1977) found two maxima peaks for water molds i.e. during summer and autumn in temperate lakes and spring and autumn in subtropical lakes. The present findings also reveal a definite periodicty pattern for the occurrence of aquatic fungi. Most of the chytridiaceous fungi occurred in post-monsoon and winter while, Saprolegniaceous fungi occurred in monsoon and winter months. Maximum forms with luxurient growth existed during November to February.

Thereafter, it showed a gradual decline and most of the forms disappeared in mid-summer, i.e. April of May. This observation fully agree with the findings of Chaudhary *et al* (1947), Dayal and Tandon (1962) and Srivastava(1967b).

The pattern of seasonal periodicity of aquatic fungi in both the lakes of Bhopal shows that the members of Chyridiales appeared in the month of September or October and existed upto March and disappeared in mid-summer. *Karlingia aurantiaca* was an exception which occurred in all seasons.

Members of Blastocladiales like Catenophlyctis variabilis appeared twice a year, first during July to September and second during January and February, while *Blastocladia sparrowii* was noted only during February to April.

Saprolegnia diclina and *Saprolegnia ferax* occurred in all seasons but *Saprolegnia furcata* was predominantly found in March and April and rarely in October.

The first appearance of species of *Achlya* was reported either in the end of July or in the beginning of August which showed an appreciable growth upto September. After this period most of the members of this genus disappeared and reappeared in November end or December and continued upto February, later on these forms start disappearing from March.

Aphanomyces laevis and *Aphanomyces sp.* occurred throughout the year. While species of *Dictyuchus* occurred only during July, August and from December to February.

Hughes (1962) placed Saprolegniaceous fungi in two groups viz., one with centric and subcentric oospores, showed marked seasonal periodicity and variation in abundance and other with eccentric oospores had no such descernible pattern. Centric and subcentric forms were least susceptible for temperature variations. During the present investigation, centric or subcentric and eccentric oospore bearing species did not show any particular seasonal periodicity. The number of occurred species belonging to both the oospore groups were almost same. Rattan et al (1980) also observed equal ratio of centric, subcentric and eccentric forms.

Members of Lagenidiales and Peronosporales occurred during October, November and February to June. Thus it is evident that when members of Saprolegniales were rare, members of Lagenidiales and Peronosporales alongwith constant species of other groups become dominant. Hence it can be concluded that members of Chytridiales and Saprolegniales prefer almost same climatic conditions. While members of Peronosporales require a distinct environmental conditions than that of other groups.

The occurrence of total aquatic fungi and members of dominant group Saprolegniales followed the same pattern during the course of the present investigation. In Upper Lake maximum fungal forms were recorded in both the years when water temperature was 18-20°C, pH 8.2-8.5, total alkalinity 81.5-100 mg/1, calcium hardness 14.5 -33.5 mg/1, chloride 9.3 -12.2 mg/1, nitrite-nil, nitrate 0.07-0.11 mg/1 and phosphate 0.01-0.11 mg/1.

Similarly in Lower Lake maxima peaks were recorded when prevailing physico-chemical conditions showed a water temperature between 18.5 and 20.2°C, pH 7.4 and 7.7, total alkalinity 105 and 123.2 mg/l dissolved oxygen 4.2 and 7.9 mg/l, calcium hardness 76.5 and 80.2 mg/l, chloride 24.2 and 34.2 mg/l, nitrite 0.004 and 0.005 mg/l, nitrate 0.06 and 0.13 mg/l and phosphate 0.03 and 0.08 mg/l.

The optimum physico-chemical conditions for the occurrence of members of Chyridiales and Saprolegniales were almost same. But members of Peronosporales had a wide and distinct physico-chemical preference, because they occurred in all seasons with very low to high valuesof these parameters.

From the foregoing discussion it can be concluded that temperature is one of the most important factors responsible for the occurrence of aquatic fungi. It is seen that low temperature high dissolved oxygen, low total alkalinity, low chloride, low nitrite and high phosphate content of water favoured the fungal occurrence, while the effect of pH, calcium hardness and nitrate was found to be insignificant.

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